ASEXUAL INHERITANCE IN THE VIOLET

(Viola odorata)

A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF CORNELL UNIVERSITY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

BY

ROY DAVID ANTHONY

Reprinted from Technical Bulletin No. 76
New York Agricultural Experiment Station, March, 1920

TECHNICAL BULLETIN No. 76. MARCH, 1920.

New York Agricultural Experiment Station.

GENEVA, N. Y.

ASEXUAL INHERITANCE IN THE VIOLET (*Viola odorata*).

ROY D. ANTHONY.

PUBLISHED BY THE STATION.

BOARD OF CONTROL.

GOVERNOR ALFRED E. SMITH, Albany.
COMMISSIONER CHARLES S. WILSON, Albany.
IRVING ROUSE, Rochester.
FRANK M. BRADLEY, Barkers.
CHARLES C. SACKETT, Canandaigua.
CHARLES R. MELLEN, Geneva.
JOHN B. MULFORD, Lodi.
C. FRED BOSHART, Lowville.
PARKER CORNING, Albany.

OFFICERS OF THE BOARD.

COMMISSIONER CHARLES S. WILSON, *President.*
WILLIAM O'HANLON, *Secretary and Treasurer.*

STATION STAFF.

WHITMAN H. JORDAN, SC.D., LL.D., *Director.*
†ALBERT R. MANN, A.M., *Agricultural Economist.*
GEORGE W. CHURCHILL, *Agriculturist and Superintendent of Labor.*
REGINALD C. COLLISON, M.S., *Agronomist.*
†T. LYTTLETON LYON, PH.D., *Chemist (Agronomy).*
JAMES E. MENSCHING, M.S., *Associate Chemist (Agronomy).*
JAMES D. HARLAN, B.S., *Assistant Agronomist.*
WILLIAM P. WHEELER, *First Assistant (Animal Industry).*
ROBERT S. BREED, PH.D.,
†WILLIAM A. STOCKING, JR., M.S.A., *Bacteriologists.*
HAROLD J. CONN, PH.D., *Associate Bacteriologist.*
JOHN W. BRIGHT, M.S.,
GEORGE J. HUCKER, M.A., *Assistant Bacteriologists.*
FRED C. STEWART, M.S.,
†DONALD REDDICK, PH.D., *Botanists.*
WALTER O. GLOYER, M.A., *Associate Botanist.*
MANCEL T. MUNN, M.S., *Assistant Botanist.*
LUCIUS L. VAN SLYKE, PH.D., *Chemist.*
RUDOLPH J. ANDERSON, PH.D.,
†LEONARD A. MAYNARD, PH.D., *Bio-Chemists.*
ARTHUR W. CLARK, B.S.,
RICHARD F. KEELER, A.B., *Associate Chemists.*
MORGAN P. SWEENEY, A.M.,
OTTO MCCREARY, B.S.,
WILLIAM F. WALSH, B.S., *Assistant Chemists.*
WALTER L. KULP, M.S.,
HAROLD L. WINSTON, B.S.,
MILLARD G. MOORE, B.S., *Assistant Chemists.*
GEORGE A. SMITH, *Dairy Expert.*
JAMES D. LUCKETT, M.S.A., *Editor and Librarian.*
PERCIVAL J. PARROTT, M.A.,
†GLENN W. HERRICK, B.S.A., *Entomologists.*
HUGH GLASGOW, PH.D.,
*FRED Z. HARTZELL, M.A. (Fredonia), *Associate Entomologists.*
ROSSITER D. OLMSTEAD, B.S.,
CLARENCE R. PHIPPS, B.S., *Assistant Entomologists.*
ULYSSES P. HEDRICK, SC.D., *Horticulturist.*
†ROLLINS A. EMERSON, SC.D., *Geneticist.*
†WILLIAM H. CHANDLER, PH.D., *Pomologist.*
‡ ROY D. ANTHONY., M.S.A.,
*FRED E. GLADWIN, B.S. (Fredonia),
ORRIN M. TAYLOR,
GEORGE H. HOWE, B.S.A., *Associate Horticulturists.*
WILLIAM C. STONE, M.S.,
EDWARD H. FRANCIS, M.A.,
THEODORE E. GATY, B.S., *Assistant Horticulturists.*
JESSIE A. SPERRY, *Director's Secretary.*
FRANK E. NEWTON,
WILLARD F. PATCHIN,
LENA G. CURTIS,
MAE M. MELVIN,
MAUDE L. HOGAN,
K. LORAINE HORTON, *Clerks and Stenographers.*
ELIZABETH JONES, *Computer and Mailing Clerk.*

Address all correspondence, not to individual members of the staff, but to the NEW YORK AGRICULTURAL EXPERIMENT STATION, GENEVA, N. Y.

The Bulletins published by the Station will be sent free to any farmer applying for them.

Connected with Grape Culture Investigations.
† Members of the faculty of the New York State College of Agriculture affiliated with this Station.
‡ Resigned to accept position at Pennsylvania State College.

TECHNICAL BULLETIN No. 76.

ASEXUAL INHERITANCE IN THE VIOLET (*Viola odorata*).[1]

ROY D. ANTHONY.

SUMMARY

In the improvement of fruit varieties the question of fixity of type in asexual propagation is of very considerable importance. The use of any of the tree fruits in a study of this problem would obviously extend the experiment far past the activity of a single investigator. In order to hasten work on this question the double violet, Marie Louise, which is propagated asexually, was used in a study of the effect of selection upon the length of blossom stem. Observations were also made of the inheritance of high and low yield.

Four selection groups were made: long-stem plants of high yield, long-stem plants of low yield, short-stem plants of high yield, and short-stem plants of low yield.

The first year it was not realized how important a rôle plant vigor would play and so no record of this factor was made. Since then the plants have been graded for vigor twice each season.

One of the greatest difficulties encountered has been to find the best methods of showing the year's work and of making the selections for the following year. The method of selecting the plants for propagation was changed after two years.

Two sets of charts were used, one where the yield and stem-length of individual plants or of clonal groups are correlated with vigor and a second series showing the influence of location in the house upon yield, stem-length, and vigor. The length of all blossom stems is reported in one-half inch units and this unit is employed in the charts.

Correlation tables are given for the three factors for the entire house for each year of the experiment and for each of the four selection groups for the last year.

For purposes of comparison, the four selection groups were reduced to the same vigor by means of the regression coefficient.

Environmental factors caused considerable variation within the same greenhouse, especially the first year of the experiment.

The second year, the vigor and yield were approximately the same for the long-high and short-high groups but there was a lower stem-length average in the short-stem than in the long-stem selection.

[1] Also presented to the faculty of the Graduate School of Cornell University as a thesis in partial fulfillment of the requirements for the degree of doctor of philosophy.

This second year four plants were grown from every plant selected as a parent the first year. The record of these four plants showed that many of the first selections, based on the performance of one plant and without a knowledge of its vigor, were not correct.

The third year the two high-yielding selections gave a slightly higher yield than the low selections but the difference was less than twice the probable error. At the same time in the two high-yielding selections the difference in stem-length in favor of the long-stem group was about five times the probable error and in the low-yielding selections about nine times.

The fourth year there were supposed to be sixty-four plants from a common parent in 1914. In the long-stem selections, the high-yielding group averaged 3.108 ± 0.441 blossoms more than the low-yielding plants. In the short-stem selection the high-yielding plants averaged 5.787 ± 0.478 more than the low-yielding plants. In both the high-yielding and low-yielding selections the long-stem plants averaged, respectively, 0.361 ± 0.036 units and 0.495 ± 0.041 units longer than the short-stem plants.

The fifth year of the experiment, in the long-stem selections the high-yielding plants averaged 1.847 ± 0.754 blossoms more than the low-yielding plants. In the short-stem selections the high-yielding plants showed a gain of 4.970 ± 0.767 blossoms. The long-stem groups in both the high and low yielding selections gained $0.368 \pm .046$ and $0.346 \pm .048$ units, respectively.

The process of selection has really been one of isolation whereby certain clonal lines have been selected out of the miscellaneous population purchased in 1914. We seemingly have proved only the existence of asexually inherited differences which probably were present before the experiment was begun. No attempt has been made to find when or how such differences arose.

Tho the existence of such differences in the violet makes it seem more probable that there may be differences within a single variety of any fruit, the labor and the technical difficulties involved render it inadvisable for a nurseryman to attempt to find beneficial variations among fruits by bud selection.

INTRODUCTION

THE PROBLEM

All commercial fruits of America are propagated by asexual means. This fact creates a fundamental difference in the problem of the improvement of our present fruit varieties as compared with the improvement of most vegetables and field crops where reproduction is by sexual means.

The development of the idea of pedigree and all it involves has had such a profound influence upon the live-stock industry that it

is only natural for the fruit-grower to be influenced in his thought of his trees by this same idea. The growth of this trend of thought has been hastened by the exploitation of the term "pedigree" by a number of nurserymen who have sought by its use to convince the buyer that their trees were better than ordinary trees, tho the exact grounds upon which this statement was based seem frequently to be uncertain even in the minds of the nurserymen themselves.

Since 1896, the Geneva Station has been working on a problem in orchard fertilization where the question of the fixity of type in asexual propagation is of considerable importance. That year an orchard of Ben Davis trees was planted for a fertilizer experiment. The trees were then top-worked to Rome, the buds all coming from a single tree. In 1912 a problem in selection within a clonal line was started when buds were taken from the highest and from the lowest yielding trees in each fertilizer block and budded on own-rooted Spy stocks. These were planted on a uniform soil and are now nearly ready to begin fruiting.

At about the time this second test was started, an attempt was made to study the fixity of type in the Baldwin by planting an orchard of trees secured from every part of the country and showing as wide a diversity as possible in their "pedigree." It is too early yet to know what the value of this last experiment will be, but owing to the conditions surrounding the orchard it is doubtful if it can be relied upon to show conclusive results.

It is obvious that work of this sort with species as slow in coming to maturity as are the tree fruits, must, of necessity, run far past the span of the working life of a single investigator. Even with the bush and small fruits progress would still be slow and these fruits are very susceptible to environmental changes. Therefore, in order to hasten the work on this problem, it was decided, in the spring of 1914, to grow the double violet, Marie Louise, in the greenhouse and to study the effect of selection upon the length of stem of the blossoms. That fall eight hundred plants were purchased from a commercial grower and planted in the greenhouse.

The first question to be answered was whether from a mixed population types, or strains, could be isolated which would hold true to their selection year after year. The occurrence of "sports" in many horticultural crops is well known, altho when we consider the opportunities for their production the number that have been isolated and proved to reproduce themselves is almost negligible. Some recent investigations would seem to indicate that citrus is an exception and that this genus is in a state of change, producing new types frequently.

One variety of apple commonly grown in New York, the Twenty Ounce, has rather recently produced three sports, while a fourth can probably be credited to it. It is doubtful, however, if this number of sports has been found in all the other fruits grown in this State. Of course such sports represent sufficiently great changes to

be seen readily and to stand out from the minor fluctuations due to environment. Whether or not there are heritable differences too small to be detected in the commercial plantations is a question of fundamental importance to all engaged in the attempt to improve our fruits.

As the first five years' work with the violet seems to throw some light on this subject and as this year marks the beginning of the second phase of the problem, namely, whether by further selection isolated types may be shifted in either direction or even split into a multiplicity of types, it has seemed best to publish the data at this time.

LITERATURE

So many excellent discussions of the general subject of bud variation have appeared in the last few years that it would seem unnecessary to present a very extensive bibliographic review. However, attention should be called to certain of these publications.

The potato was the first asexually propagated plant in which improvement was generally sought by means of selection. A review of much of the early work with this plant is presented by Stuart (1915).[2]

The results of one of the most successful experiments in the selection of somatic variations were presented by Stout (1915). His work with Coleus did much to call the attention of investigators to this problem.

Dorsey (1916) has given us an excellent review of the literature bearing on several phases of the question of bud variation.

Jennings' work (1916) with Difflugia is very interesting as it involves a quite different type of reproduction. The chapter devoted to bud selection in Babcock and Clausen's book (1918) is a splendid critical study of the different phases of this problem.

The most recent contributions from the horticultural standpoint have been Shamel's articles (1918) dealing with citrus fruit improvement.

DESCRIPTION OF MATERIAL USED

The double violet, Marie Louise, for fifty years has been one of the most widely grown varieties in commercial and amateur houses. It is entirely sterile and is propagated by the separation of shoots from the original plant. So far as we have been able to find, the variety runs very uniform. While one or two so-called strains have been produced, the fact that they have never made their way into commercial culture would seem to indicate that they differed little if at all from the true variety. Altho the previous treatment of the 800 plants with which the experiment was started was not known, it is safe to assume that they would trace back to a very few parent

[2] Reference to Literature Cited, page 30.

plants in a few generations as nurserymen are constantly propagating from their best plants and each healthy plant yields eight or ten cuttings.

These plants were placed in the south house of a range of three running east from the main house. The south-east corner of the house is exposed to some of our coldest winds and fluctuations of several degrees in temperature have been noted between this corner and the sheltered north-west corner. The main house at the west not only shelters from the wind but also has a tendency to decrease the light received in the north-west quarter of the house. This point will be discussed somewhat in detail later. Within the house are two tile-bottom benches, each holding 400 plants in fifty rows of eight plants to the row. These two benches will be referred to as the north and south benches, respectively.

New plants are propagated each year either by allowing roots to form on the shoots, which are put out at the base of the crown, before the cuttings are taken, or the shoots are taken off just as the roots start to form. The shoots are then put in flats filled with sand. When root-growth is well started, the shoots are transferred to thumb pots and later, to larger pots and placed in cold frames for the summer. The plants are set in the benches about the first of September.

The first few blooms that form usually have very short stems and are imperfect and these are discarded without measuring. The first regular picking is made about the middle of October. With a slight jerk the stems separate readily from the plant and the entire length from the base of the blossom is measured in units of one-half inch.

As it was necessary to tabulate the results before plants could be selected for propagation for the following year, the last harvest record was usually made early in March, at a time when the plants were giving nearly maximum yields.

METHODS

House records.— Tho the experiment was to deal primarily with blossom-stem length, it was decided to study inheritance of high and low yield also as yield records had to be taken in getting stem-lengths. As plants were selected for long and short stem and high and low yield, this gave four selection groups: long-stem plants of high yield, long-stem plants of low yield, short-stem plants of high yield, and short-stem plants of low yield. In order to shorten the records and the discussion, these groups are usually referred to as follows: long-high, long-low, short-high, and short-low, respectively.

The records are taken in the greenhouse on large sheets 14 by 17 inches, cross-ruled into quarter-inch squares. The plant number is placed at the left and the date at the top. Each flower-stem is measured and the length to the nearest one-half inch placed in the

next square. When each harvest is over, a vertical line is drawn outside of the last record of the highest yielding plant. In this way the first records of the following harvest for all plants are in the same vertical line of squares, making it easy to study the yield fluctuation of any particular plant from harvest to harvest, and showing the relation of any plant to the maximum yield of that harvest.

With conditions at their best, the bed is picked over every week or ten days but in very cold weather it may be three weeks or more between harvests. When the large record sheets are filled they are totaled for each plant. In an average season, when the third series of sheets is filled, the records are discontinued and propagation commenced for the following year. For the first year the various factors were studied for each of these three harvest periods but since then only for the total harvest.

When the experiment was begun it was not realized how important a rôle plant vigor would play and so the first year no record was made of this factor but the need of it was clearly seen when it became necessary to select plants for propagation for the following year. There seemed to be no feasible way of weighing the plants or measuring their leaf surface and so the vigor was estimated in percentage, the most vigorous plants being graded as 100 and a few plants, with only a half dozen or so leaves and practically no blossoms, graded as 10. Two persons cooperated in this work, each checking the other, and it is doubtful if a third person would have shifted any of the plants more than ten points in the vigor score. The vigor was taken twice, once when the plants were coming into full bloom early in the winter, and a second time just before the selection of the plants for propagation for the next year. In computing final records the average of the two observations was used.

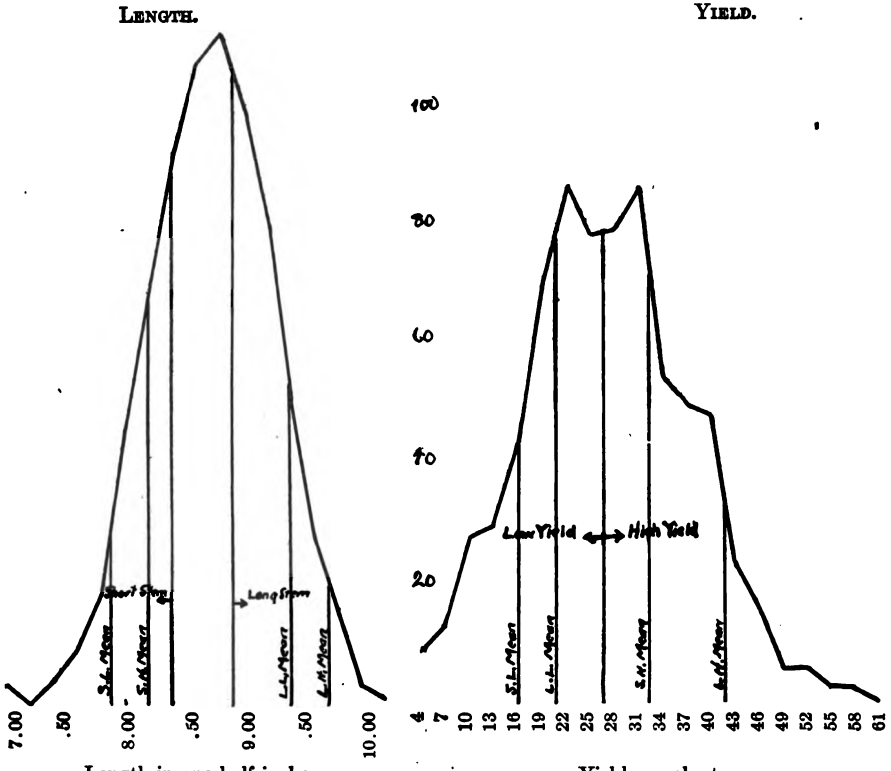
In a very general way, plants recorded as having a certain vigor were somewhat alike from year to year; but, because of the variations of the plants in different seasons, it is not possible to compare the vigor records of two different years with each other except in so far as each is considered as a statement of the relative values of the plants for that particular year.

Statistical methods.— In order to simplify the problem of studying the plants and especially of making selections for the next year's propagation, the number, yield, and stem-length of each plant was placed on a single card and the cards grouped according to the line of selection. These cards could then be shuffled for any factor, and frequency charts and correlation tables very quickly prepared. This method has resulted in a considerable saving in time and has been a very important help in analyzing the data.

One of the greatest difficulties encountered in the experiment was to find the best method of showing the results of the year's work and of making the selections for the following year. The method of selecting the plants for propagation was not the same for the first

two years as is now used. In these early years the records were thrown into frequency tables and certain maximum or minimum yields and lengths selected until the number of plants which it was planned to propagate was isolated. This is well illustrated by Chart I which shows the selection standards for the first year in connection with the frequency curves of length and yield. The lines from which the arrows are drawn show the selection limits.

CHART I.— FREQUENCY CURVES OF LENGTH AND YIELD, 1914–15.



Length in one-half inches. Yield per plant.

By selecting the plants from the frequency curve and without knowledge of their vigor, any plants which were high-yielding because of abnormally high vigor were selected and the same was true with plants of low yield, due to lack of vigor. This objection has now been overcome by a somewhat different method of selection. Each plant or group of plants is plotted according to vigor on a chart with a common base line and with the yield plotted above and the stem-length below the vigor line. (See Chart IV.) In this way two

TABLE I.— STATISTICAL VALUES FOR THE ENTIRE HOUSE AND FOR THE SELECTION GROUPS FOR FIVE YEARS.

GROUPS.	STANDARD DEVIATION.			AVERAGE.			NUMBER OF PLANTS.
	Length.	Yield.	Vigor.	Length.	Yield.	Vigor.	
Total house 1914–15....	.510±.008	10.464±.183	.....	8.836±.012	27.969±.259	.....	742
Total house 1915–16....	.672±.017	10.970±.217	18.05±.357	8.600±.018	33.590±.306	49.99 ±.505	581
Group totals							
L. H. 1915–16.....	.674±.021	11.03±.345	15.59±.488	8.822±.029	32.44±.488	47.00± .690	232
L. L. 1915–16.....	.772±.030	11.24±.446	20.58±.818	8.515±.043	34.18±.631	51.25±1.156	144
S. H. 1915–16.....	.611±.028	9.97±.466	14.60±.683	8.369±.040	31.77±.659	49.19± .963	104
S. L. 1915–16.....	.648±.030	10.29±.488	20.78±.986	8.683±.043	36.24±.691	55.44±1.396	101
Total house 1916–17....	.602±.011	11.50±.217	17.65±.333	8.489±.016	31.74±.306	53.17± .471	639
Group totals							
L. H. 1916–17.....	.592±.020	11.04±.380	17.47±.601	8.546±.028	30.08±.537	49.34± .850	192
L. L. 1916–17.....	.579±.023	10.51±.431	17.47±.712	8.664±.033	31.73±.605	56.09±1.007	137
S. H. 1916–17.....	.665±.024	11.93±.435	17.69±.645	8.511±.033	34.56±.603	56.43± .895	171
S. L. 1916–17.....	.498±.020	11.74±.475	16.45±.665	8.213±.028	30.61±.672	51.65± .941	139
Total house 1917–18....	.585±.010	6.83±.124	22.01±.401	7.535±.015	16.36±.176	52.59± .567	683
Group totals							
L. H. 1917–18.....	.394±.016	5.44±.220	20.55± .834	7.749±.026	17.54±.312	51.88±1.180	138
L. L. 1917–18.....	.643±.023	5.94±.220	27.49±1.020	7.804±.033	14.52±.311	52.12±1.443	165
S. H. 1917–18.....	.475±.017	7.46±.277	20.31± .756	7.461±.025	20.69±.393	57.19±1.070	164
S. L. 1917–18.....	.525±.017	5.92±.192	19.86± .644	7.278±.024	13.73±.271	49.90± .911	216
Total house 1918–19....	.650±.011	10.92±.197	13.31± .240	8.331±.016	36.36±.278	81.44± .339	699
Group totals							
L. H. 1918–19.....	.574±.021	9.63±.357	13.72± .509	8.353±.030	35.56±.505	79.24± .720	165
L. L. 1918–19.....	.618±.022	11.09±.404	14.56± .531	8.557±.031	35.28±.572	82.60± .751	171
S. H. 1918–19.....	.712±.025	11.06±.402	12.22± .444	8.088±.036	41.06±.569	82.67± .628	172
S. L. 1918–19.....	.661±.022	10.72±.370	12.79± .441	8.173±.031	35.26±.515	81.20± .614	191

TABLE I.—STATISTICAL VALUES FOR THE ENTIRE HOUSE AND FOR THE SELECTION GROUPS FOR FIVE YEARS (*concluded*).

GROUPS.	COEFFICIENT OF CORRELATION.			REGRESSION COEFFICIENT.			COMPUTED MEAN VALUES.		
	Vigor and length.	Vigor and yield.	Length and yield.	Length to vigor.	Yield to vigor.	Length to yield.	Length.	Yield.	Vigor.
Total house 1914–15	.....	.....	.415±.019	.....	.....	.020	8.836±.012	27.969±.259	.....
Total house 1915–16	.807±.009	.739±.012	.729±.012	.030	.449	.044	.....	.....	.....
Group totals									
L. H. 1915–16	.779±.017	.775±.017	.727±.021	.033	.488	.044	8.920±.029	34.080±.488	49.996±.505
L. L. 1915–16	.706±.028	.771±.022	.699±.028	.026	.421	.047	8.483±.043	33.650±.631	49.996±.505
S. H. 1915–16	.724±.031	.741±.029	.524±.047	.030	.509	.032	8.393±.040	32.180±.659	49.996±.505
S. L. 1915–16	.895±.013	.699±.034	.678±.036	.027	.346	.042	8.537±.043	34.360±.691	49.996±.505
Total house 1916–17	.611±.016	.793±.009	.716±.012	.020	.517	.037	.....	.....	.....
Group totals									
L. H. 1916–17	.694±.024	.749±.021	.623±.029	.023	.473	.033	8.635±.028	31.893±.537	53.177±.471
L. L. 1916–17	.640±.033	.728±.026	.692±.029	.021	.438	.038	8.603±.033	30.460±.605	53.177±.471
S. H. 1916–17	.613±.031	.786±.019	.638±.030	.023	.530	.035	8.437±.034	32.837±.603	53.177±.471
S. L. 1916–17	.669±.031	.752±.024	.621±.035	.020	.537	.026	8.243±.028	31.436±.672	53.177±.471
Total house 1917–18	.600±.016	.550±.017	.387±.021	.015	.171	.033	.....	.....	.....
Group totals									
L. H. 1917–18	.723±.027	.445±.045	.548±.039	.013	.117	.039	7.758±.026	17.695±.312	52.591±.567
L. L. 1917–18	.764±.021	.636±.030	.647±.030	.012	.137	.070	7.812±.033	14.587±.311	52.591±.567
S. H. 1917–18	.590±.033	.515±.038	.262±.048	.013	.172	.016	7.397±.025	19.903±.393	52.591±.567
S. L. 1917–18	.555±.031	.475±.034	.391±.038	.014	.141	.036	7.317±.024	14.116±.271	52.591±.567
Total house 1918–19	.554±.017	.628±.012	.379±.021	.027	.746	.022	.....	.....	.....
Group totals									
L. H. 1918–19	.645±.030	.655±.030	.461±.040	.026	.419	.028	8.409±.030	36.484±.505	81.447±.339
L. L. 1918–19	.655±.029	.733±.023	.515±.037	.027	.558	.028	8.525±.031	34.637±.572	81.447±.339
S. H. 1918–19	.660±.028	.642±.029	.536±.036	.038	.581	.034	8.041±.036	40.359±.569	81.447±.339
S. L. 1918–19	.480±.036	.592±.031	.377±.041	.024	.496	.023	8.179±.032	35.389±.515	81.447±.339

points are located for a single plant or group of plants, the one directly above the other, and the line connecting them passes thru the vigor value of the plant. As an aid in selection, a straight line was drawn thru each population in such a way as to divide the members in the various vigor classes into nearly equal parts. Inasmuch as the individuals near this line, the average plants, were discarded whenever possible, this method of dividing the population was deemed sufficiently accurate. To check this point, however, in several cases the straight line was determined by the formula, $y=mx+n$. The two lines were found to differ but little. Values lying above the line would then represent high-yielding or long-stem plants and those below the line low-yielding or short-stem plants.

By selecting from this chart it was possible to find those plants which were above or below the average at any particular vigor. This method has been used the last two years with very satisfactory results. In 1915–16 the selections were made on the basis of the average performance of the four plants tracing from a common origin the previous year. The following year the average of the sixteen plants with common origin was used and so on for each year, the total number tracing from a single plant in 1914 increasing by multiples of four each year.

A second series of charts (Chart III) is used to show the influence of location in the house upon the three factors studied and the relative fluctuation of those factors. These charts are also useful in showing the sudden jumps that frequently occur in passing from one type of selection to another when the plants lie in adjacent rows.

Correlation tables are made for the three factors for the entire house and for each of the four selection groups, and for each of these the following values are computed: Coefficient of correlation of vigor and length, vigor and yield, and length and yield; the standard deviation of length, yield, and vigor; the mean values of length, yield, and vigor; regression coefficients; and the corrected means where yield and length have been reduced to a common vigor by the regression coefficients.

These values are summarized in Table I and in the appendix are placed the correlation tables for the entire house for each year of the experiment and the correlations for each selection group for the last year. To include all the correlation tables seemed unnecessary since those which were selected show the general trend of the correlations.

A study of the correlation tables themselves without reference to computed values is of considerable help as it shows roughly the degree of correlation, the approximate averages, and the presence of any abnormal plants which need further study. If any sporting occurs in the factors studied it can be quickly detected by this means.

In studying the 1915–16 records a number of the correlations were worked out for the first and for the third periods of harvest.

The correlation between vigor and yield in the first group of pickings was low but for the third group considerably higher except for the short-low group and in the total this correlation is still higher with all groups. A study of the formula for correlation, $r_{yv}=\frac{\Sigma d_y d_v}{n\sigma_y\sigma_v}$, shows the mathematical reason for this. The total yields for the third group were of course considerably higher than for the first group of pickings and the total for the three groups very much higher. Thus, we have a constantly increasing Σdd in the numerator, while in the denominator the standard deviation for vigor does not fluctuate materially and the standard deviation for yield does not increase as rapidly as the summation so that we have a constantly increasing value for the coefficient of correlation. The fundamental reason is probably that by the third period of harvest the plants have reached their maximum production and under such conditions probably show greater correlation than earlier in the season. This variation in the correlation is another reason why it is difficult to compare different years with each other.

In Table II are summarized for the last four years the corrected mean yield and mean stem-length for the house and the differences for the contrasted selection groups. Such a summary is very convenient in the analysis of the data.

TABLE II.—FOUR YEAR SUMMARIES OF YIELDS AND STEM-LENGTHS.

Yield and length for each selection group computed for each year to average vigor of house.

YIELDS.			STEM-LENGTHS.		
Group yields.	Long stem.	Short stem.	Group lengths.	High yield.	Low yield.
1915–16					
High yield....	34.08 ±.488	32.18± .659	Long stem..	8.920±.029	8.483±.043
Low yield.....	33.65 ±.631	34.36± .691	Short stem..	8.537±.040	8.537±.043
Gain or loss.	.43 ±.797	—2.18± .954		.383±.049	—.054±.060
1916–17					
High yield....	31.893±.537	32.837±.603	Long stem..	8.635±.028	8.603±.033
Low yield.....	30.460±.605	31.436±.672	Short stem..	8.437±.034	8.243±.028
Gain.....	1.433±.808	1.401±.902		.198±.044	.360±.044
1917–18					
High yield....	17.695±.312	19.903±.393	Long stem..	7.758±.026	7.812±.033
Low yield.....	14.587±.311	14.116±.271	Short stem..	7.397±.025	7.317±.024
Gain.....	3.108±.441	5.787±.478		.361±.036	.495±.041
1918–19					
High yield....	36.484±.505	40.359±.569	Long stem..	8.409±.030	8.525±.031
Low yield.....	34.637±.572	35.389±.515	Short stem..	8.041±.036	8.179±.032
Gain.....	1.847±.754	4.970±.767		.368±.046	.346±.048

More should be said of the use of the regression coefficient. A study of the coefficients of correlation shows the high degree of correlation between vigor and yield and vigor and stem-length. For this reason it became necessary to find some way of reducing the various groups to a common vigor in order to compare yield and stem-length. This can be done with sufficient accuracy by means of the regression coefficient.[3] The four selection groups were reduced to the same vigor as the house average by multiplying the difference between the group average vigor and the house average vigor by the regression coefficient. If the group vigor was less than the house average this value was added to the group average length; if the group vigor was greater than the house average, it was subtracted from the group length.

INFLUENCE OF LOCATION IN HOUSE UPON YIELD AND STEM-LENGTH

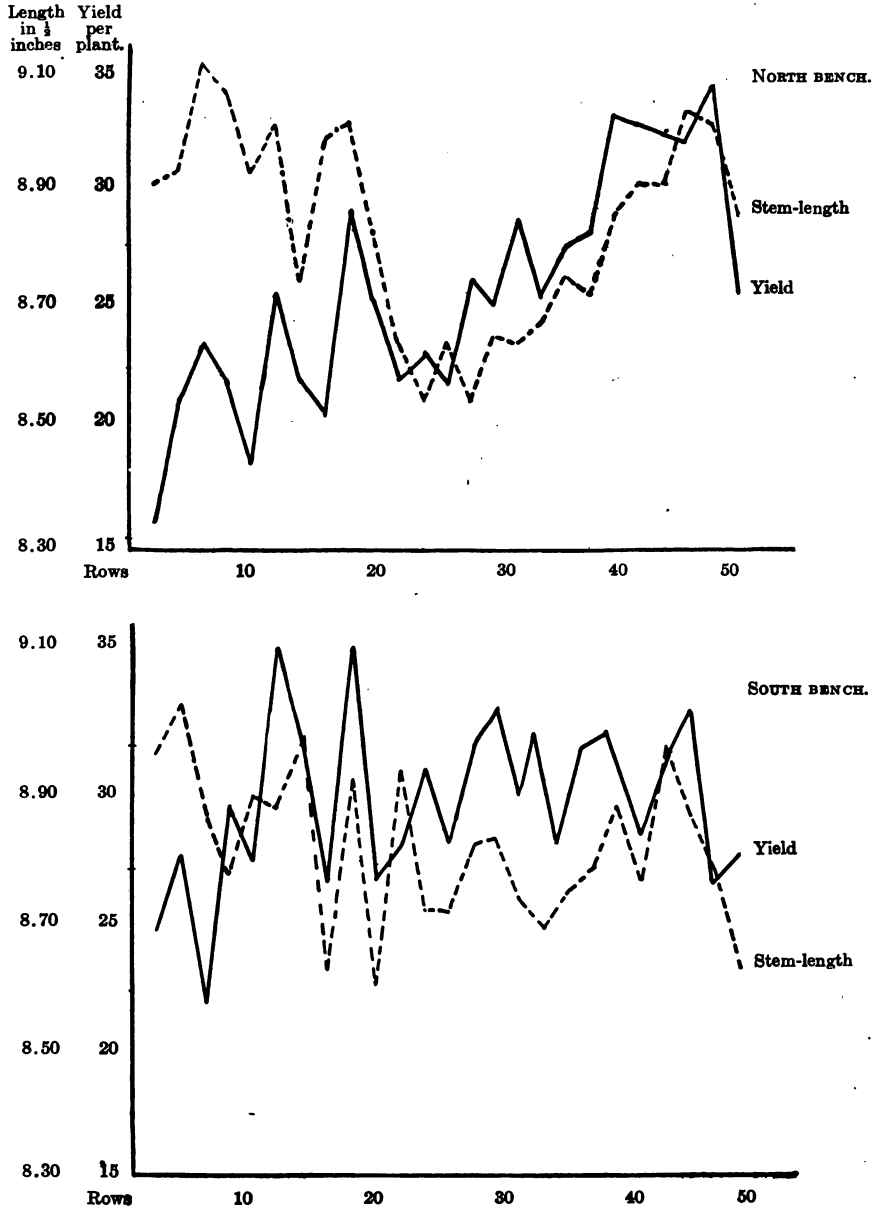
On first thought, one would expect that the house conditions were sufficiently uniform so that environmental variations could be excluded but a study of the year's record shows this not to be the case. Even after five years' study all of the factors causing variation can not be stated positively but the two most influential are probably temperature and light. As both of these differ in different seasons we find, in studying the house from year to year, indications of yearly variations so that any conclusions drawn from the first year's record must be applied to any other year only with many reservations.

Chart II shows the yield and average stem-length for 1914–15 for groups of sixteen plants in two adjacent rows as they stood in the two benches. Care was taken to have the soil and cultural treatment as uniform as possible and so it seems safe to say that any fluctuations of the groups are due to the influence of location in the house upon plant growth. In other years variations may be due to the selection as well as to the influence of position.

On the chart we notice a fluctuation in the north bench which has appeared to a greater or less extent in every year and has been an important factor in complicating the results in this bench. In the west half of the bench (the left side of the chart), the yield shows a peak extending about one-third of the way down the bench and there is a remarkable rise in the stem-length of this area. Year after year in this part of the bench have been the most vigorous plants, those with the longest stems, and, usually, those with the highest yield in the entire house. The eastern half of the bench this first year shows a constantly increasing yield and stem-length. This increase does not seem to be as pronounced in other years and just why it should show to the extent that it does this first year is

[3] The formula used was: Regression coefficient of length to vigor $= r_{LV} \frac{\sigma_L}{\sigma_V}$.

CHART II.— INFLUENCE OF LOCATION IN HOUSE UPON YIELD AND STEM-LENGTH, 1914–15.



not known. In the south bench there are some rather sharp fluctuations in stem-length and, in general, the yield fluctuates with the length. Taking the whole of the south bench into consideration no marked change seems to show which could be laid to environment. In the light of the other years' records, however, the tendency of the stem-length to increase slightly at the west end while the yield decreases slightly is significant, and it is probably safe to say that the western half of the bench is somewhat more favorably located for stem-length development than the eastern half.

GENERAL DISCUSSION OF RESULTS FOR 1914–15

The first year no record was taken of vigor, only the total yield of each plant and the stem-length of each blossom being recorded. Altho the lack of a record of vigor decreases the value of the first year's results to some extent, our knowledge of the general relations of stem-length and yield gathered from the other four years enables us to interpret the results for the first year with considerable accuracy.

House values.— Because of the lack of the vigor record, it was possible to correlate only length and yield. The coefficient of correlation for the entire house was $0.415 \pm .019$, very considerably lower than the following year when it was $0.729 \pm .012$. This low correlation is due to the failure of the two factors to respond in the same degree to the house conditions affecting the west end of the two benches. This condition seems more noticeable this year than in the following years. The average length for the house was high, $8.836 \pm .012$ units, in proportion to the yield of $27.969 \pm .259$ blooms, as shown in Table III.

TABLE III.— FIVE YEAR SUMMARIES.

Mean values for entire house.

YEAR.	YIELD.	LENGTH.	VIGOR.
1914–15	27.969±.259	8.836±.012	.....
1915–16	35.590±.306	8.600±.018	49.996±.505
1916–17	31.747±.306	8.489±.016	53.177±.471
1917–18	16.368±.176	7.535±.015	53.591±.567
1918–19	36.367±.278	8.320±.016	81.447±.339

It is probable that the commercial grower from whom these plants were purchased had been selecting for high vigor for years, and thus had been unconsciously selecting for long stems and high yield.

Selection of plants for 1915–16.— The method used in selecting the plants for propagation during the first years has already been described. Because of the errors involved in this method and because

of lack of knowledge of the vigor of the plants, many were marked for propagation along the four lines of selection which, in the light of our present knowledge, should have been discarded or should have been included in a different class from the one in which they were placed.

GENERAL DISCUSSION OF RESULTS FOR 1915–16

Before it was realized to what extent the factors under observation would be influenced by house conditions, the plants for the 1915–16 crop were planted in the house. The long-high and short-high groups were placed in the south bench and the long-low and short-low groups in the north bench. As the total number of plants this year was kept to about 700, all the groups save the long-high occupied somewhat less than a quarter of a bench.

House values.— From Chart III, where each point represents the average for twelve adjacent plants, it will be seen that, on the south bench, the vigor and yield were approximately the same for the two groups but that the line of stem-length is somewhat lower in the short-stem selection than in the long-stem selection.

On the north bench the region of high yield discussed under the previous year's data does not begin until the seventh or eighth row but seems to carry to the east to about the thirty-second row, covering practically the entire bench so far as it is occupied by these two groups. In this bench the fluctuations in vigor make it impossible to observe any certain differences in stem-length or yield in the two selections. Referring to Table II, where the summaries for the four years are given, we note that the average stem-lengths for these two groups do not show a significant difference while the stem-length difference in the south bench is .383 ± .049 units in favor of the long-stem selection. Owing to the differences between the two benches it is difficult to draw any conclusion with regard to yield. On the west ends of the two benches the high-yield is slightly better than the low-yield selection when reduced to a common vigor. Most of the short-low plants on the north bench lie in a more favorable position than the short-high plants on the south bench and this probably accounts for this group being the higher yielding one contrary to the selection.

Selection of plants for 1916–17.— Each half row in the year 1915–16 originated from a single plant of the previous year. At the time that that single plant was selected to act as a parent only the one year's record was available to use in judging in which group the plant should fall. At the end of 1915–16 the record of the four plants with a common parentage showed clearly that a number of groups did not belong in the classes in which they had been placed. Some indeed were so far out of the class in which they were first placed that it seemed wise to select them for continued propagation in one

CHART III.— INFLUENCE OF LOCATION IN THE HOUSE ON YIELD, STEM-LENGTH, AND VIGOR, 1915–16.

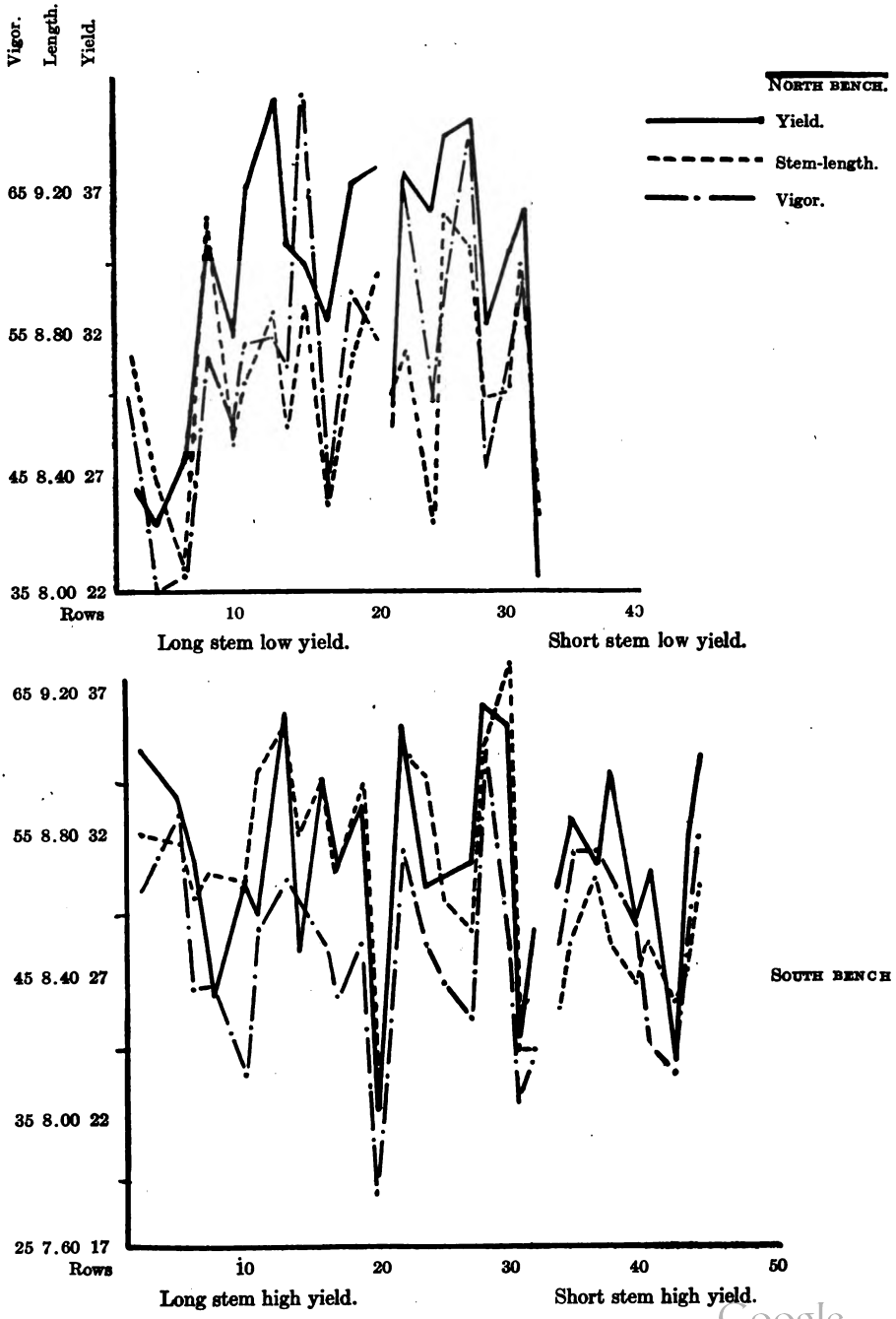
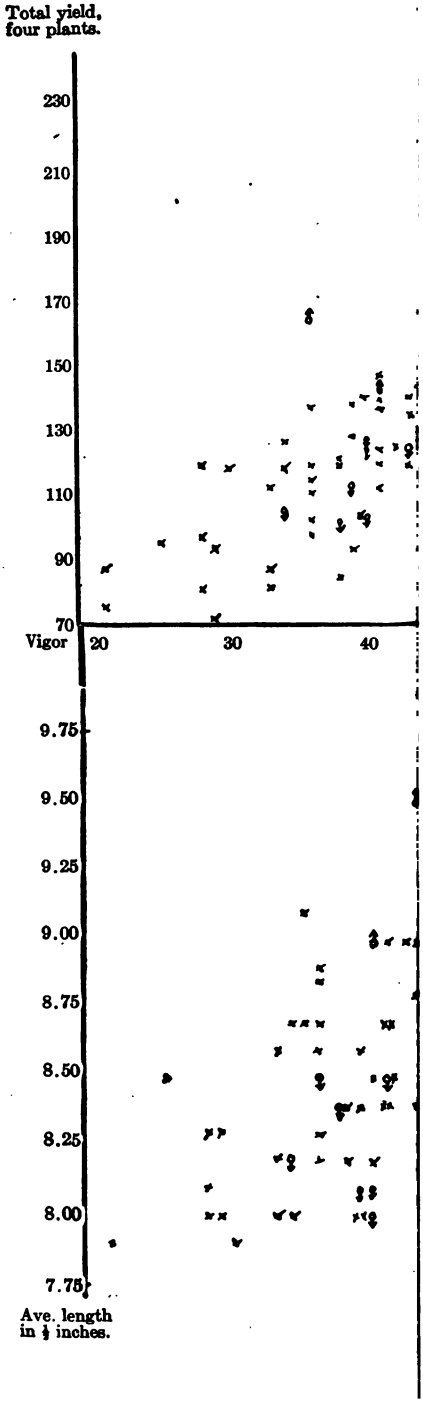


CHART IV.— RELATION

Record



Ch

Vigor.

65 !

55 !

45 !

35 !

65 !

55 !

45 !

35 !

25 7

of the other groups in which they now appeared to fall. Others of these abnormal plants were discarded. As all these plants were included in the group tabulations they have served to smooth out the results to some extent and hide any effects due to the selection.

Chart IV shows the distribution of the groups of four plants. The groups selected for further propagation are marked with the arrow, the direction of the arrow indicating the direction of the selection. The method illustrated in this chart was not developed until later and an inspection of the chart shows that some groups were retained which should have been discarded while many were discarded which should have been retained.

GENERAL DISCUSSION OF RESULTS FOR 1916–17

This year there were sixteen plants tracing back to a single plant placed in the house in 1914. These sixteen plants were set out in two rows of eight each, extending across the bench. Groups representing the same type of selection were scattered thru the house in such a way that the influence of house variations was probably very largely done away with so far as the summaries are concerned.

From an inspection of the graphs of the values for length, yield, and vigor, plotted for position in the house as shown in Chart V, it would seem that there was somewhat less fluctuation on the north bench than was the case the first two years, especially in regard to yield and stem-length. There was, however, a tendency for the first sixteen rows from the west to be somewhat better than the next sixteen. In the previous year the high area on the north bench seemed to extend from about Row 10 thru Row 31. There was considerably more vaiation in the south bench than in the previous two years, there being an especially high area between Rows 8 and 18. The different selection classes were so scattered thru the house that no one class seems to have been affected by these areas more than the others.

House values.— Toward the latter part of the season, nematodes were found on the roots of several plants. These decreased the vigor and the yield of blossoms on a number of plants but in spite of this the house average yield was 31.747 ± .306 from November 3, 1916, to March 5, 1917. (See Table III.) The average stem-length for the same period was 8.489 ± .016 units, or 4.244 inches. It is probable that, because of the nematodes, our vigor standard was slightly lower than in the previous year as the average length of practically 8.5 units was from plants with an average vigor of 53.177 ± .471, while in 1915–16 the average length of 8.600 ± .018 was from plants with an average vigor of practically 50.

Group yields.— In the two groups selected for long stems, the high-yielding selection gave 1.433 ± .808 blooms more than the low selection and in the two short-stem groups the difference between the

CHART V.— INFLUENCE OF LOCATION IN HOUSE ON YIELD, STEM-LENGTH, AND VIGOR, 1916–17.

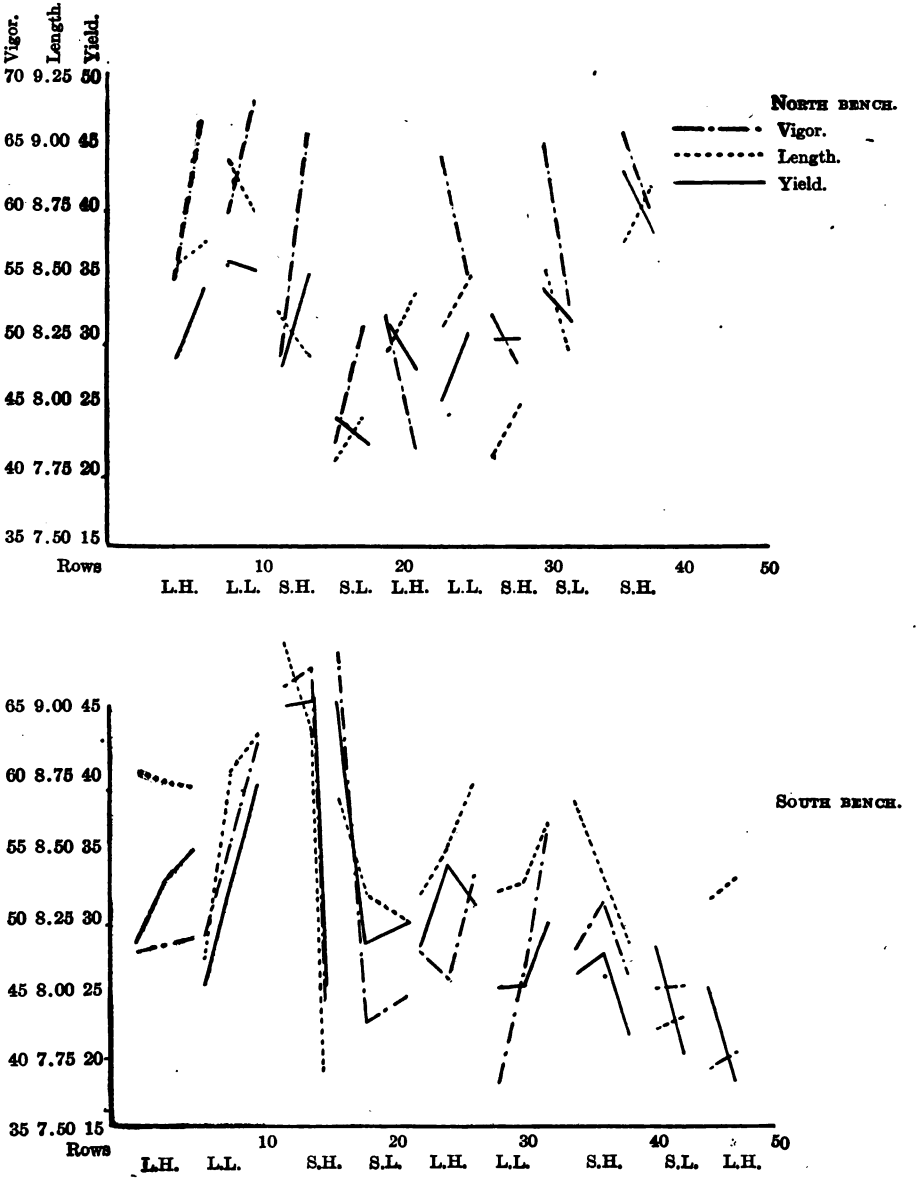
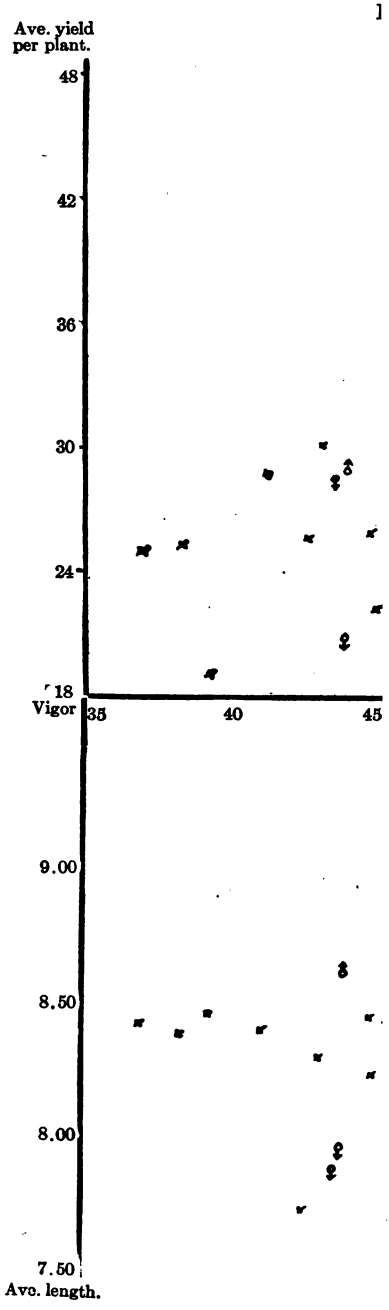


CHART VI.— REI



CHART

Vigor.	Length.
70	9.2
65	9.0
60	8.7
55	8.5
50	8.2
45	8.0
40	7.7
35	7.5

65	9.0
60	8.7
55	8.4
50	8.1
45	8.0
40	7.
35	7.

high and low selection was 1.401 ± .902 blooms. (See Table II.) This is not a large difference and in each case it is less than twice the probable error of the difference.[4]

Group lengths.— In the two high-yielding selections the average stem-length of the short-stem group was .198 ± .044 units below the average for the long-stem group and in the two low-yielding selections the average stem-length of the short-stem group was .360 ± .044 units below the long-stem group. (See Table II.) In the high-yielding group this difference is about five times the probable error and in the low-yielding group about nine times the probable error. It must be borne in mind that the selection, which is really a process of isolation, is not acting rapidly enough at the end of the first two selection periods for us to expect any very great difference. Such differences as these were, therefore, a surprise to all engaged in the work and may be considered as very significant in throwing light upon the trend of the experiment.

Selection of plants for 1917–18.— In making the selection for the following year, groups tracing back to a common parent plant in 1914 were treated as units. Chart VI shows the distribution of the average values for these groups and those selected for further propagation.

GENERAL DISCUSSION OF RESULTS FOR 1917–18

It was planned for this year that there should be sixteen rows of four plants each, all tracing back to a single plant in the 1914–15 population. It was not possible in all cases, however, to continue propagating at the rate of four to one and so some of the groups fall below a total of sixty-four. Plants having a common origin were not separated, but those groups which had a common selection were scattered through the house in order to eliminate, so far as possible, the influence of house variations. It would have been somewhat better had the units of sixty-four plants been split up into two or four groups and placed in different parts of the house.

House values.— The very unusual cold, together with the age and poor condition of the house, resulted in a very light yield. The average yield for the house for a period extending from November 20, 1917, to March 12, 1918, was 16.368 ± .176 blossoms. The average stem-length was 7.535 ± .015. But one vigor record was taken this year, that at the end of the picking season. The average vigor was 53.591 ± .567. (See Table III.)

Group yields.— In the long-stem selections the high-yielding group averaged 3.108 ± .441 blossoms more than the low-yielding plants. In the short-stem selection the high-yielding plants averaged 5.787 ± .478 more than the low-yielding plants. (See Table II.)

[4] The probable error of the difference is found by extracting the square root of the sum of the squares of the probable errors of the means which are compared.

Group lengths.— In the high-yielding selection the long-stem plants averaged .361 ± .036 units longer than the short-stem plants, and in the low-yielding selection the long-stem plants were, on the average, .495 ± .041 units longer. In comparison with the probable errors these differences are sufficiently large to remove any doubt of their value. (See Table II.)

Selecting plants for 1918–19.— The general correlations of the three factors are shown graphically in Chart VII. Here, also, are indicated the plants retained for the next year.

This chart shows even more clearly than the figures given above that our process of isolation has separated out distinct groups. Thus, in the north-west quarter of the house, the long-low group and the short-high group have the positions of the stem-length and yield lines reversed at nearly the same vigor. The yield line of the long-high group is much higher at lower vigors than in the short-low group. On the west end of the south bench, the two contrasted selections, long-low and short-high, show a complete reversal in the relative positions of the yield and length lines.

In Chart VIII the average yield and average stem-length of groups of twelve adjacent plants are plotted to the average vigor. Since there were as high as sixty plants in a single line, the points on the chart do not now represent the entire performance of a particular selection as has previously been the case in this type of chart.

GENERAL DISCUSSION OF RESULTS FOR 1918–19

Propagating the selected plants at the rate of four to one, there should be 256 tracing back to a common origin in 1914. Owing to the vicissitudes of propagation, however, this number was not retained in every case. In one or two cases the number was very considerably cut down, but in such cases this was done largely because of lack of room or the uncertainty as to whether that particular line would be continued further. The larger populations were broken into three groups and placed in different parts of the house. In this way it is probable that whatever house fluctuations there were have not seriously influenced the final average results. In general, the house fluctuations this year were not extreme. In Chart IX, the usual peak is seen on the north bench but it is not extreme and seems to affect yield more than the other factors. The south bench shows many minor fluctuations but, on the average, it is fairly uniform.

House values.— The total yield per plant from October 18, 1918, to January 31, 1919, was 36.367 ± .278. The average stem-length was 8.33 ± .016. (See Table III.) The first two harvests of the season were very heavy and, as is always the case with the first harvest, there was a high proportion of short-stem blossoms. In other years the first harvest has been discarded because of these

CHART VII.—INFLUENCE OF LOCATION IN HOUSE ON YIELD, STEM-LENGTH, AND VIGOR, 1917–18.

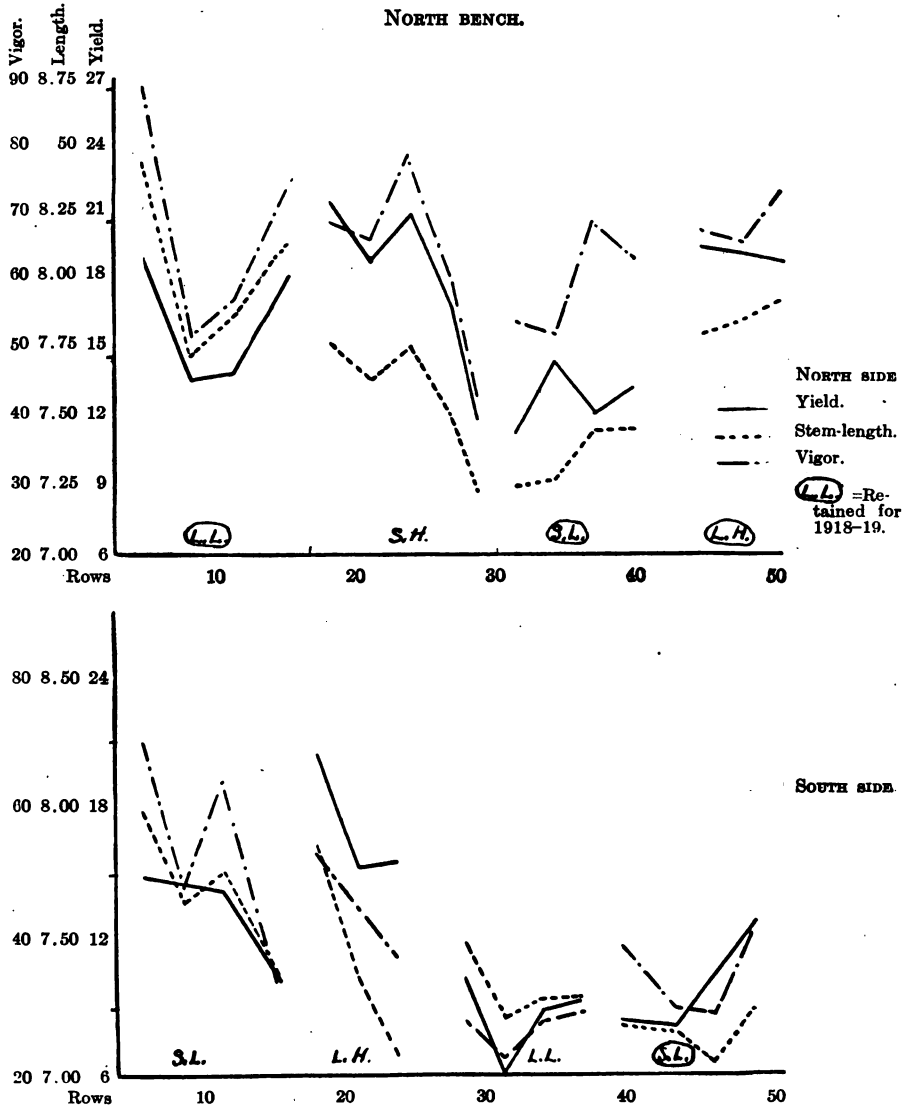


CHART VII (*continued*).

SOUTH BENCH.

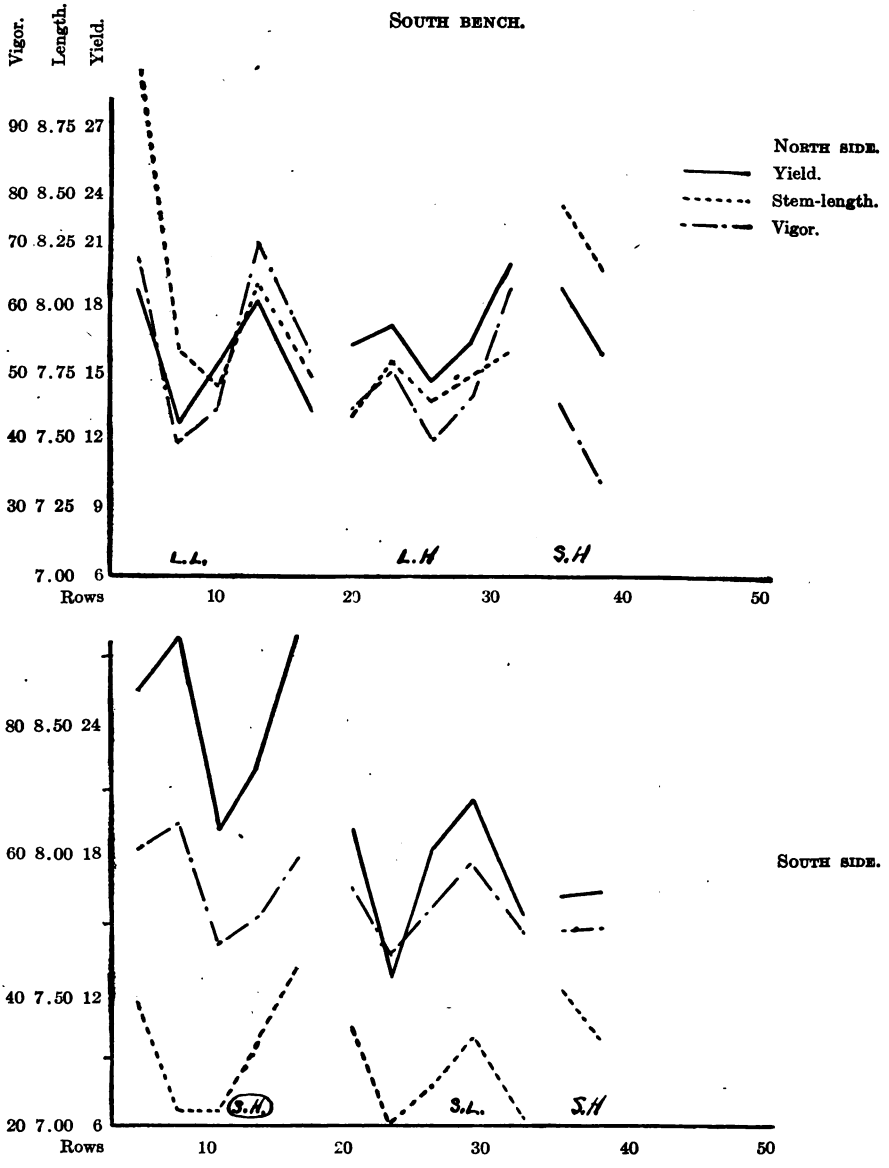
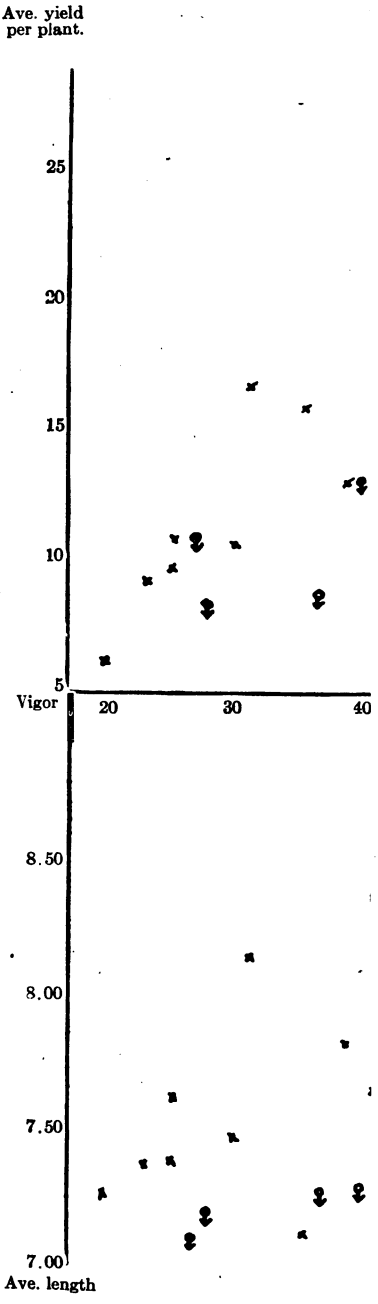


CHART VIII.—RELA



Vigor.	Length.		
90	8.75		
80	8.50		
70	8.25		
60	8.00		
50	7.75		
40	7.50		
30	7 25		
	7.00		
	Rov		
80	8.50	2	
60	8.00	1:	
40	7.50	12	
20	7.00	6	
	Rows		

CHART IX.— INFLUENCE OF LOCATION IN HOUSE ON YIELD, STEM-LENGTH, AND VIGOR, 1918–19.

Averages of 8 plants.

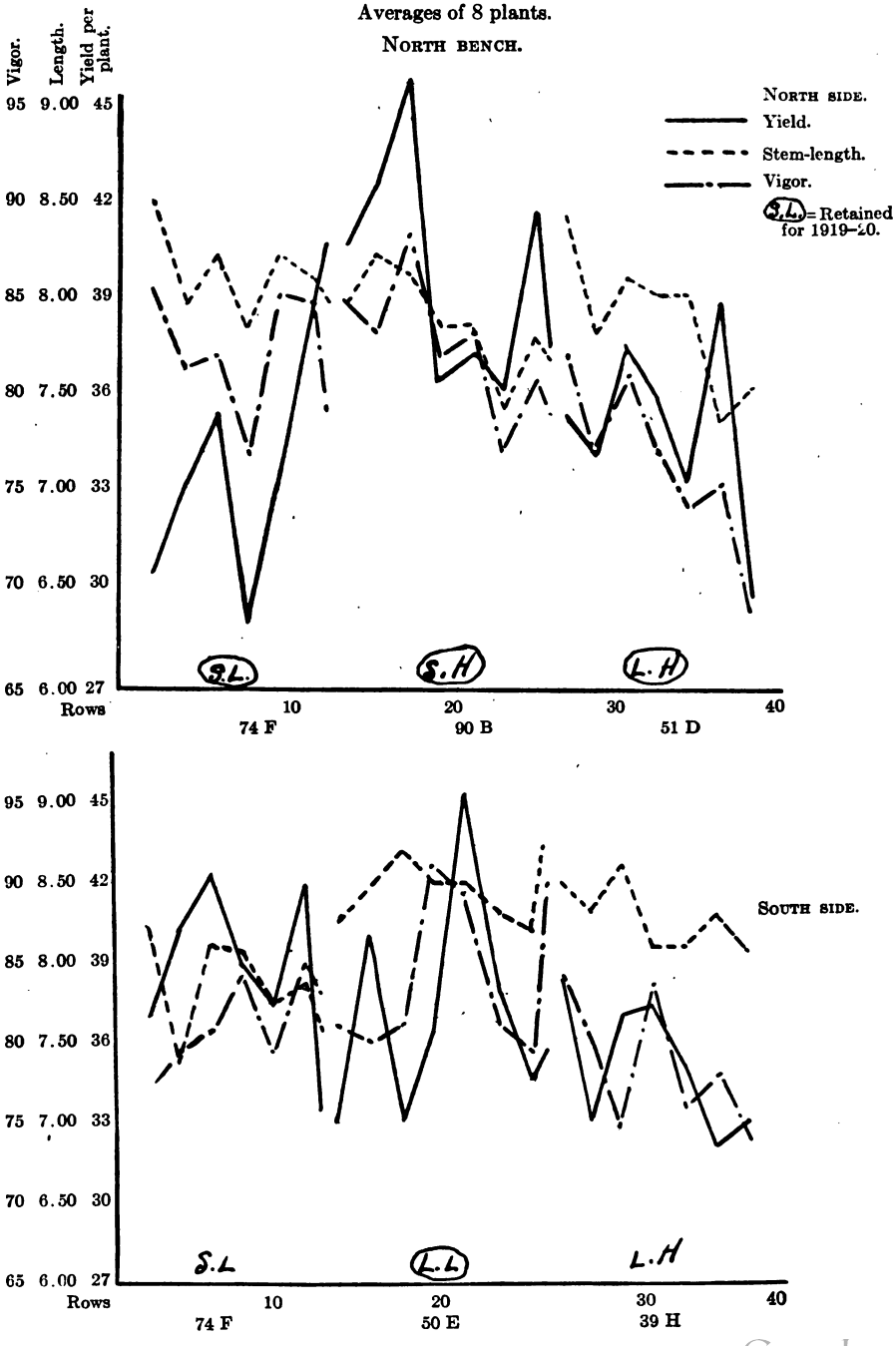


CHART IX (*Continued*).

SOUTH BENCH.

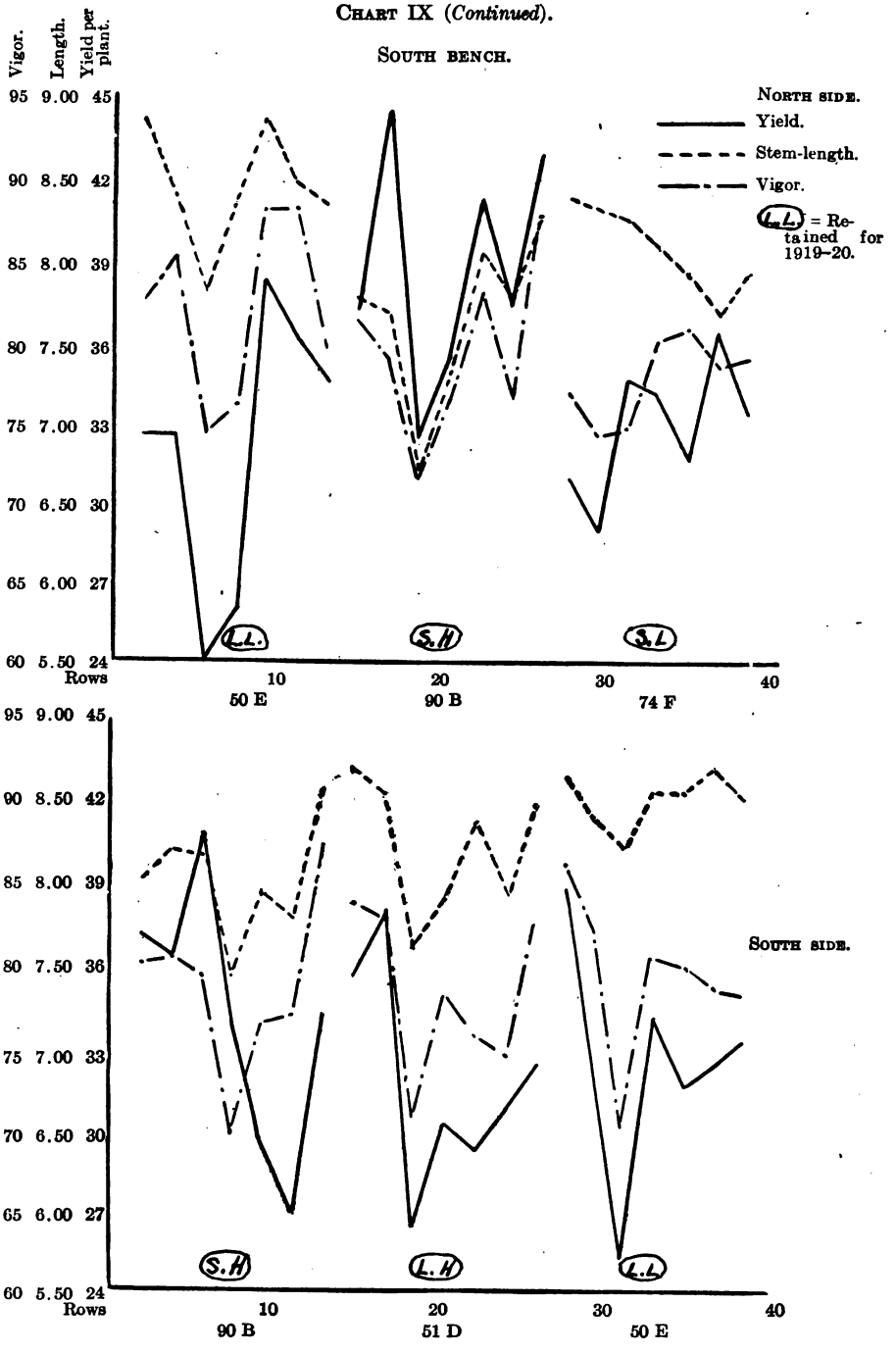
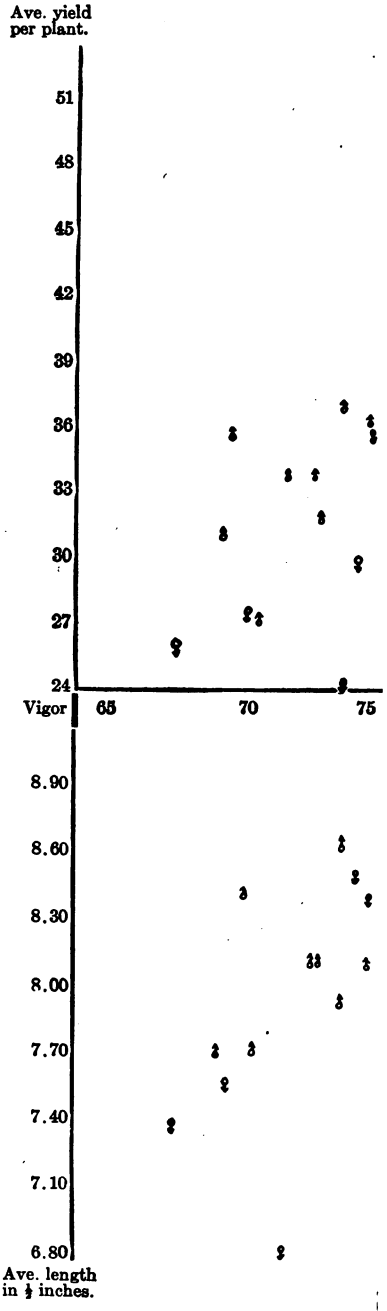


CHART X.— RELATION

R



Vigor.	Length.
95	9.0
90	8.5
85	8.0
80	7.5
75	7.0
70	6.5
65	6.0
60	5.50

H

95	9.00
90	8.50
85	8.00
80	7.50
75	7.00
70	6.50
65	6.00
60	5.50

Rc

short-stem blossoms but, on account of the large number of blooms in the first harvest this year, it was decided to retain it in the records. Because of including these short stems, the average length has probably been decreased several tenths of a unit. In the third group of harvests, that extending from December 24 to January 31, a very considerable proportion of the plants averaged well above ten units in length. The average vigor this year was 81.447 ± .339. In other years it has been the custom to arrange the vigor scale in such a way that the average would be approximately 50, but this year such a large proportion of the plants showed extreme vigor that this did not seem advisable. Plants recorded as having a vigor of 50 per cent this year were probably fairly comparable with those having a similar vigor record last year.

Group yields.— In the long-stem selections, the high-yielding plants averaged 1.847 ± .754 blooms more than the low-yielding plants. (See Table II.) This is less than the difference between the same groups in the previous year. This fact may probably be considered as another indication that our process of selection is beginning to isolate distinct groups because this year there are progeny of only two of the original plants represented in the long-high group. One of these plants, 51 D, which is the clon retained to continue the selection for another year, is not strictly a high-yielding clon, but, from its performance of other years, would be graded as somewhat above the average. It is retained, however, because it is long-stemmed and is sufficiently high-yielding to answer the purpose. In the short-stem selection the high-yielding plants gave 4.970 ± .767 blossoms more than the low-yielding plants. This great difference in yield is due to the fact that 90 B, the short-high strain, is a remarkably high-yielding group.

Group lengths.— In the high-yielding strains the long-stem plants were .368 ± .046 units longer in blossom stem-length than the short-stem plants and, in the low-yielding strain, the difference was .346 ± .048. (See Table II.) These differences are not quite as great as in the previous year but, as before explained, this is due to the inclusion in the records of a large number of short-stem blooms in the first picking which in previous years were discarded.

When the house was planted in the fall of 1918 the different lines were broken into groups, the groups being placed in different parts of the house. In all there were twelve groups. A study of these in Chart IX shows that in seven cases the relative position of the graph of both stem-length and yield indicates clearly the type of the selection of that group. In each of the other five cases, the graph of either stem-length or yield is in the position to be expected from its types of selection while the other graph is either uncertain or apparently opposite to the selection. In two of these latter cases, the two groups of 74 F on the west end of the north bench, a possible

cause for the failure to follow the selection may be suggested. If we refer back to Chart II we see that with the mixed population of 1914–15, in the area occupied by these two groups, there was a different relation between the stem-length and yield lines than in the rest of the house. As has been suggested before, this difference is probably due to a slight change in the environmental factors in the northwest corner of the house.

The way in which the plants adhere to their respective types of selection is also shown in Chart X. Here the whole population is shown in groups of eight plants and the character of the selection of each group is graphically indicated. It is remarkable the small number of groups which fall in areas occupied by groups of the opposite selection.

CONCLUSION

The first five years of selection have isolated four well-defined groups. The differences between the opposite selections are sufficiently large to show graphically on the charts of the two benches for the fourth and fifth years and, in comparison with their probable errors, make it certain that they are not due to chance variations. It is believed that variations due to lack of uniformity of conditions within the house have been so nearly eliminated that the final results are not materially affected.

When this work was started it was the opinion of those connected with it that such a result as this would not be secured and probably most pomologists would have held the same opinion. For this reason there is justification in restating certain points and showing the possible application of the results.

During the five years reported in this publication, the process of selection has really been one of isolation whereby certain clonal lines have been selected out of the miscellaneous population purchased in 1914. In nearly every case each plant within the clon has been the parent of four plants used the following year. It follows, then, that we seemingly have proved only the existence of asexually inherited differences which probably were present before the experiment was begun. No attempt has been made to find when or how such differences arise.

That differences have been found in the violet which could be passed on from bud generation to bud generation does not prove that similar differences may be found in the apple but it does make it seem more probable that such differences exist. Unfortunately, from the standpoint of practical application, the labor and the technical difficulties involved in proving that an observed difference is really transmissable and not simply a temporary response to an environmental change make it seem inadvisable for a nurseryman to attempt such a problem.

The four selection groups now contain only five pure lines, each tracing back to a single plant in 1914. Whether these clonal lines are pure lines in the sense that Johannsen has applied that term or whether they are simply stages beyond which we will go to greater differences, thru further selection, is now the problem.

PLANS FOR CONTINUING THE EXPERIMENT

There had been no selection within any clonal line up to the spring of 1919. At that time it was decided that fifty parent plants would be saved in each of the four types of selection as this would give the 800 plants necessary to fill the house. In all but one type these fifty were selected from one clon only. As there were from 100 to 150 plants from which to select the fifty parent plants this afforded an opportunity to choose those plants which best answered the conditions of their particular type. Instead of selecting single plants, groups of four, each tracing back to a single parent the previous year, were selected.

In one group, the short-high selection, two plants were used to start two new lines in an attempt to break up a clon by selection within it. One of these plants was selected for long stem and the other for short stem. In choosing these, care was taken to find two plants which did not have a common origin until the original 1914 plant was reached. These two lines will be continued with intensive selection.

These general plans will be followed for another five years to test the fixity of the clonal lines.

ACKNOWLEDGEMENTS

Thruout the five years of the experiment Mr. Joseph Wellington has had the oversight of the propagation and the harvesting. This has involved a great deal of work and no small part of whatever value the work has is due to the care and accuracy with which the records were taken in the greenhouse. He has also assisted in the preparation of the data for publication.

The author is greatly indebted to Dr. H. H. Love of the Department of Plant Breeding of the New York State College of Agriculture for many helpful suggestions and advice in the biometrical work.

The initiation of this work was due to Dr. U. P. Hedrick. For many years he had been interested in the question of pedigree in fruit and saw the possibilities in extending this study to some plant where results could be secured more rapidly than with the apple. His direction has been one of the factors in the success of the work.

LITERATURE CITED

Stuart, Wm. 1915. Potato breeding and selection. U. S. D. A. Bul. 195.

Stout, A. B. 1915. The establishment of varieties in Coleus by the selection of somatic variations. Carnegie Inst. Wash. Pub. 218.

Dorsey, M. J. 1916. The inheritance and permanence of clonal varieties. Proc. Am. Soc. Hort. Sci. 1916.

Jennings, H. S. 1916. Heredity, variation and the results of selection in the uniparental reproduction of *D fflugia corona*. Genetics, 1 No. 5.

Babcock, E. B. and Clausen, R. E. 1918. Genetics in relation to agriculture. McGraw-Hill. New York.

Shamel, A. D., et al. 1918. Citrus fruit improvement. U. S. D. A. Buls. 623, 624, 697.

APPENDIX

TABLE IV.— CORRELATION OF YIELD AND LENGTH OF STEM.*

Total for entire house, 1914–15.

STEM-LENGTH.† CLASS AVE.	YIELD. 2	5	8	11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	TOTALS.
10.51								1													1
10.31										1											1
10.11				2								1									3
9.91									1		3	1	1	4	2	3	1				16
9.71		1			2		1	1	1	2	6	2	1	3	2		1	2	1	1	27
9.51				1		2	5	2	4	6	9	4	8	6		4	1		1		53
9.31			2	1		2	4	8	8	7	13	9	10	6	2	4	1	1		1	79
9.11		1		2	3	8	7	9	9	11	12	9	6	9	7	4		3	1		101
8.91		2	1	2	2	6	11	15	13	16	8	9	10	7	7		1				110
8.71		1	1	4	1	3	11	17	11	13	18	10	8	3	2	1	1	1		1	107
8.51		1	1	8	5	8	14	12	12	7	10	8	4	2	1	1					94
8.31	1		4	2	3	9	10	11	10	9	3	3	2	3	2	1					73
8.11		2	1	3	8	4	6	7	5	5	2		1								44
7.91	1	1	2	1	4	1	1	3	1	2	2										19
7.71	1		2		2		2			1											8
7.51				1		2			1												4
7.31																					0
7.11			1	1																	2
TOTALS.	3	9	15	28	30	45	72	86	76	80	86	56	51	43	25	18	6	7	3	3	

$r = .415 \pm .019$

* In the correlation tables it has been more convenient to arrange the factors studied with their highest values at the top of the table and because of this a positive correlation is shown by an ascending population.

† Blossom stem lengths are given in units of one-half inch.

TABLE V.— CORRELATION OF VIGOR AND STEM-LENGTH.

Total for entire house, 1915–16.

STEM-LENGTH.

VIGOR. Class Ave.	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.2	10.4	TOTALS.
100																1		1			1			3
95																1	2		1	1				5
90													1	1	1	1	2	1	1	3				11
85															1	2	1	4	2			1		11
80								1						2		3	3	4	3		2			18
75													1	3	5	4	3	3	2	6			1	28
70														1	4	4	5	2	3	3		2		24
65												2	2	4	5	4	7	5	4	2	1	2		38
60												2	3	6	4	12	6	6	3	2	1			45
55											1	3	4	9	10	3	6	4	2	2			1	45
50											4	10	13	6	10	15	7	3	1					69
45						1		1	3	3	4	9	10	4	6	11	9	4	1					66
40						2		1	2	6	9	10	12	5	4	9	1	2	1					64
35						1	2	1	5	7	8	15	11	11	4	1	2							68
30					1	1	1	3	6	6	8	3	5	4	3	1								42
25						2	2	4	3	3	2	1	1											18
20					2		2	2	1				1											8
15				2	1	2		2		3		1												11
10	2			1	1	1	1			1														7
TOTALS.	2	0	0	3	5	10	8	15	20	29	36	56	64	56	57	72	54	39	24	19	5	5	2	

$r = .807 \pm .009$

Table VI.— Correlation of Vigor and Yield.

Total for entire house, 1915–16.

Class Ave. (Vigor) \ Yield	11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74	Totals.
100														1	1			1					3
95										1		1	1			1				1			5
90									1	3	2	1		2			1	1					11
85								2		1	1	1	1	1		2				1		1	11
80								1			6	1	2	4	1		2				1		18
75							1	3	4	3	4	3	5	1	2	1	1						28
70				1			2	1	2	3	6		4	3	2								24
65					1		2	5	7	3	5	9		4			1		1				38
60				1	2	3	3	6	4	2	7	9	2	3	2		1						45
55					2	3	3	5	6	7	5	5	2	5	2								45
50					2	7	11	9	8	12	13	3	1	2			1						69
45				2	9	4	7	10	13	8	9	1	3										66
40			2	5	7	9	16	13	7	2	1	1	1										64
35		1	2	10	10	19	13	9	3			1											68
30		1	8	10	11	8	2	2															42
25	1	1	8	4	1	1	2																18
20	2	2	2		2																		8
15		4	5	2																			11
10	2	4	1																				7
Totals.	5	13	28	35	47	54	62	66	55	45	59	36	22	26	10	4	7	2	1	2	1	1	

$r = .739 \pm .012$

TABLE VII.— CORRELATION OF YIELD AND STEM-LENGTH.

Total for entire house, 1915–16.

STEM-LENGTH. CLASS AVE.	YIELD. 11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74	TOTALS.
10.40																1							1
10.20									1								1	1				1	4
10.00									1		4			1	1		2						9
9.80								3			1	2	2	2	1	1					1		13
9.60							2		4	3	5	2	1	6		2		1	1	2			29
9.40							2	3	3	2	7	10	3	3	2	1	1						37
9.20				1			5	6	5	4	4	7	4	4		1	1						42
9.00				1	1	5	10	9	7	6	18	2	5	9	3		1						77
8.80			1	3	4	4	7	12	17	12	5	3	4	2									74
8.60				1	2	9	8	5	1	6	4	5	2	1	1								45
8.40			3	7	3	11	9	12	8	5	5	2	1										66
8.20		1	2	3	9	9	11	7	5	6	1	1	2										57
8.00			3	4	12	5	4	2	2	1	1												34
7.80	1	1	3	4	5	7	1	5			1												28
7.60	1		6	2	6	3	2		1		1		1										23
7.40		4	5	4	2		1																16
7.20	2			3	1	1			1														8
7.00		3	2	1		1	2																9
6.80	1	2	1		1																		5
6.60		1																					1
6.40																							0
6.20		1	1																				2
6.00																							0
TOTALS.	5	13	27	34	46	55	64	64	56	45	57	34	25	28	8	6	6	2	1	2	1	1	

$r = .729 \pm .012$

TABLE VIII.— CORRELATION OF VIGOR AND STEM-LENGTH.

Total for entire house, 1916–17.

VIGOR. CLASS AVE.	STEM-LENGTH. 6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	9.91	10.11	TOTALS.
100																	1			1
95												1			1	1		2		5
90										2		2	2	1	4	8	3	1	2	25
85							1					1	1	8	2	2	2			17
80								1	1	3		1	5	5	5	1	2			24
75									3	4	2	3	3	4	1	1	2	1		24
70					1	1				2	7	4	5	9	5	1				35
65							1	1	3	5	10	5	8	9	5	1				48
60			1				1	1	9	5	8	6	5	11	10	2				59
55						1	4	5	13	9	8	9	4	10	5	1				69
50	1			1			7	5	9	10	13	10	5	6		2	1			70
45						3	4	5	15	12	12	6	1	5	1	1				65
40				1	2	7	8	6	12	17	9	10	3	6						81
35				1	3	4	2	6	9	6	5	4		1						41
30			1	1		2	11	5	9	5	2	3								39
25	1			1		3	6	1	2	5	3									22
20				1	1	1	3	2	2	1										11
15						2		1												3
TOTALS.	2	0	2	6	7	24	48	39	87	86	79	65	42	75	39	21	11	4	2	

$r = .611 \pm .016$

TABLE IX.— CORRELATION OF VIGOR AND YIELD.

Total for entire house, 1916-17.

VIGOR. CLASS AVE.	YIELD. 5	8	11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	TOTALS.
100																1								1
95													1	1	1	1				1				5
90								2			1		2	1	3	6	2	3	1	3		1		25
85											2	1	2	4	3	1	1		1	1			1	17
80								1	1			1	4	5	4	6	1	1						24
75					1				1	1	2	2	7	2	2	3	1		1	1				24
70							2		4	5		3	6	4	5	1	1	3		1				35
65							1		6	8	5	7	9	3	4	3		1	1					48
60			1			1	2	4	5	10	12	12	6	2	2				2					59
55						4	5	2	11	11	13	9	5	6	3									69
50		3			1	3	8	8	12	12	7	6	8	1		1								70
45					3	2	14	13	17	6	7	1	1	1										65
40		1	2	4	4	9	19	12	16	3	8	1	1		1									81
35			4	2	2	8	10	8	4	1	1	1												41
30			4	3	14	8	6	2	2															39
25			2	5	7	4	2	1		1														22
20		4	1	2	3	1																		11
15	1	1	1																					3
TOTALS.	1	9	15	16	35	40	69	53	79	58	58	44	52	30	28	23	6	8	6	7	0	1	1	

$r = .793 \pm .009$

TABLE X.— CORRELATION OF YIELD AND STEM-LENGTH.

Total for entire house, 1916–17.

Yield. Class Ave.	Stem-length. 6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	9.91	10.11	Totals.
71																	1			1
68																		1		1
65																				0
62													1	1	2	1	1		1	7
59														2	2	1	1			6
56											2		3		1		2			8
53									1				1	2	1	1				6
50									1	3		1	3	4	4	4	2		1	23
47							1		2	3	3	3	3	4	3	4		2		28
44									4	4	2	3	1	11	4	1				30
41						1	1	1	1	2	7	8	7	11	5	4	3	1		52
38							2		4	5	5	7	4	10	6	1				44
35						1	1	3	7	10	9	7	5	8	3	4				58
32							2	3	9	6	12	10	7	8			1			58
29			1			3	4	5	16	10	12	13	3	6	6					79
26					2		5	1	12	17	8	4	1	3						53
23				1	2	6	6	12	8	14	11	3	1	3	2					69
20					1	1	7	4	11	7	3	4	1	1						40
17				2	1	4	12	2	8	2	2	1	1							35
14				2		3	3	4	2	1	1									16
11	1		1	1	1	2	1	3		1	2	1		1						15
8	1					3	3		1	1										9
5								1												1
Totals.	2	0	2	6	7	24	48	39	87	86	79	65	42	75	39	21	11	4	2	

$r = .716 \pm .012$

TABLE XI.— CORRELATION OF VIGOR AND STEM-LENGTH.

Total for entire house, 1917–18.

VIGOR. CLASS AVE.	STEM-LENGTH. 5.41	5.61	5.81	6.11	6.31	6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	TOTALS.
100										1	2	1	1	3	2	5	1	2	2	1		2	23
90										1	3	7	7	12	4	6	3	2	2				47
80									1	3	3	10	5	16	6	3	1	2					50
70							3	2	12	5	14	10	8	19	8	3		1					85
60						1	5	3	13	12	11	9	7	11	4	1	1		1				79
50	1					2	4	2	18	15	21	16	12	16	2		1						110
40				1	3	7	6	10	26	20	23	18	9	6	2		1						132
30		1		1	1	2	2	6	12	18	23	12	1		1								80
20			3	1	3	9	14	8	16	8	7	4	2										75
10						1				1													2
TOTALS.	1	1	3	3	7	22	34	31	98	84	107	87	52	83	29	18	8	7	5	1	0	2	

$r = .600 \pm .016$

TABLE XII.— CORRELATION OF VIGOR AND YIELD.

Total for entire house, 1917–18.

Class Ave.	Yield. 2	5	8	11	14	17	20	23	26	29	32	35	38	41	Totals.
100					4	3	4	3	5	1	2			1	23
90			1	2	6	8	10	7	7	3		1	1	1	47
80			1	3	6	5	12	9	7	2	3	1	1		50
70			1	15	13	11	16	14	8	3		3		1	85
60		1	2	15	13	8	20	9	6	3	1	1			79
50		1	9	22	24	18	10	11	9	2	2	2			110
40		5	11	30	34	19	18	6	7	2					132
30		4	13	22	19	12	8	1	1						80
20	3	19	22	16	10	5									75
10	1		1												2
Totals	4	30	61	125	129	89	98	60	50	16	8	8	2	3	

Vigor.

$r = .550 \pm .017$

TABLE XIII.— CORRELATION OF YIELD AND STEM-LENGTH.

Total for entire house, 1917–18.

YIELD. CLASS AVE.	STEM-LENGTH. 5.41	5.61	5.81	6.11	6.31	6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	TOTALS.
41											2	1											3
38												1				1							2
35									1	4	1	1		1									8
32									1	1	3			1				1				1	8
29					1					4		2	1	2	3	1		1	1				16
26						1		1	9	5	3	7	5	13	1	3		1	1				50
23							4	4	5	2	10	7	2	10	7	4	2	1		1		1	60
20						1	1	1	12	9	17	14	9	20	6	4	2	1	1				98
17	1					2	3	2	9	9	18	13	8	12	4	2	3	2	1				89
14					2	3	5	3	17	23	23	15	16	13	5	3			1				129
11			1	2		3	5	10	23	18	23	22	6	9	2		1						125
8				1		4	11	5	16	9	4	4	4	2	1								61
5		1	1		4	7	5	4	5		3												30
2			1			1		1					1										4
TOTALS.	1	1	3	3	7	22	34	31	98	84	107	87	52	83	29	18	8	7	5	1	0	2	

$r = .387 \pm .021$

TABLE XIV.— CORRELATION OF VIGOR AND STEM-LENGTH.

Total for entire house, 1918–19.

STEM-LENGTH.

VIGOR. CLASS AVE.	6.31	6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	9.91	10.11	TOTALS.
100										1	4	4	4	9	9	6	8	2	1		48
95								1	3	2	9	13	15	10	12	12	8	3			88
90						1	1	2	11	9	19	19	18	12	14	1	6	1		1	115
85					1	2	9	12	11	26	20	22	19	6	4	1	2				135
80				1	2	8	12	15	12	14	18	10	8	2	2	1					105
75			1	1	1	8	6	15	9	12	9	7	3	1		1					74
70	1			1	2	3	6	5	4	11	3	2	3		1						42
65				3		2	3	4	3	5	1	1	1	1							24
60			1	1	1	5	3	1	1	1	4	2			1						21
55		1	1	3		4	3	3	1		1										17
50				1	2	3	1		2	1											10
45							4	1	1	1		1									8
40			1	2	1	2	1		1												8
35				1																	1
30								2													2
25				1																	1
TOTALS.	1	1	4	15	10	38	49	61	59	83	88	81	71	41	43	22	24	6	1	1	

$r = .554 \pm .017$

TABLE XV.— CORRELATION OF VIGOR AND YIELD.

Total for entire house, 1918–19.

VIGOR. Class Ave.	YIELD. 8	11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	Totals.
100									1		3	2	5	8	5	10	5	3	2	2		2	48
95						1	3	2	3	10	6	10	14	13	9	10	2	3	1		1		88
90						5	2	4	7	12	17	17	18	14	3	10	3	1	2				115
85				1	2	8	9	9	20	26	16	15	6	11	6	1	4	1					135
80				1	6	6	9	12	14	9	19	14	5	4	4	2							105
75				1	4	9	12	11	10	9	7	3	5		1	1	1						74
70			1	2	1	6	11	5	6	4	1	4				1							42
65				1	2	3	3	4	3	1	5	1		1									24
60			1	4	2	5	1	1	3		2	1			1								21
55	1	1	3	1	4	2	4		1														17
50				4	1	2	1	2															10
45		1	1	1	2	1	1			1													8
40			2	3	2	1																	8
35		1																					1
30			1				1																2
25				1																			1
Totals.	1	3	9	20	26	49	57	50	68	72	76	67	53	51	29	35	15	8	5	2	1	2	

$r = .628 \pm .012$

TABLE XVI.— CORRELATION OF YIELD AND STEM-LENGTH.

Total for entire house, 1918–19.

STEM-LENGTH.

YIELD. CLASS AVE.	6.31	6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	9.91	10.11	TOTALS.
71															1			1			2
68												1									1
65											2										2
62											1			1	1		2				5
59										1	1	4	1			1					8
56								1	1	1	2	3	2	4	1						15
53						1		2	1	2	3	5	5	4	6	3	2			1	35
50			1			2	1	1	3	4	3		3	3	3	1	2	1	1		29
47							1	3	2	3	9	5	7	7	5	5	3	1			51
44						2	1	3	5	7	7	6	9		8	2	3				53
41						1	4	9	6	7	12	11	6	3	2	2	3	1			67
38				2	1	3	7	8	5	11	13	5	8	4	5	1	2	1			76
35					1	3	7	5	11	11	7	12	2	5	4	1	3				72
32				1		3	3	6	7	8	7	10	13	4	3	1	1	1			68
29				2		3	5	4	6	12	8	1	3	2	1	2	1				50
26					2	7	5	12	4	6	4	4	6	2	2	2	1				57
23				1	4	3	5	4	6	4	4	10	5	1	1		1				49
20		1		2	1	5	5	2	1	4	2	1	1	1							26
17			2	4	1	3	3		1	2	1	2				1					20
14	1			2		2	1	1			2										9
11				1			1					1									3
8			1																		1
TOTALS.	1	1	4	15	10	38	49	61	59	83	88	81	71	41	43	22	24	6	1	1	

$r = .379 \pm .021$

TABLE XVII.— CORRELATION OF VIGOR AND STEM-LENGTH.

Long-high group, 1918–19.

VIGOR. CLASS AVE.	STEM-LENGTH. 6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	9.91	10.11	TOTALS.
100									1			1		1				3
95							1	5	3	2	3	1	3	5	1			24
90						3		5	1	3	2	5		3			1	23
85						1	5	5	6	6	2	1		1				27
80				2	1	1	5	6	4	3	1							23
75				1	7	4	2	6	5									25
70		1	1	1	1	2	6	2	1									15
65					1	2	3	1										7
60			1				1	2										4
55				2	1	1		1										5
50	1		1			1												3
45				1	1	1												3
40		1		1														2
35																		0
30					1													1
TOTALS.	1	2	3	8	13	16	23	33	21	14	8	8	3	10	1	0	1	

$r = .645 \pm .030$

TABLE XVIII.— CORRELATION OF VIGOR AND YIELD.

Long-high group, 1918–19.

VIGOR. CLASS AVE.	YIELD. 11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	TOTALS.
100												2				1		3
95						1		2	1	2	4	5	6	2		1		24
90						1	1		1	5	3	3	3	2	4			23
85					1	1	2	6	3	4	3	1	6					27
80			1		2	2	4	3	1	5	3	1	1					23
75				1	3	7	4	6	1		2	1						25
70			1		2	4	2	2	3						1			15
65						1	1	1	1	2	1							7
60					1	1				1				1				4
55	1	1			1	2												5
50			2				1											3
45			1	1		1												3
40			1	1														2
35																		0
30						1												1
TOTALS.	1	1	6	3	10	22	15	20	11	19	16	13	16	5	5	2	0	

$r = .655 \pm .030$

TABLE XIX.— CORRELATION OF YIELD AND STEM-LENGTH.

Long-high group, 1918–19.

YIELD. CLASS AVE.	STEM-LENGTH. 6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	9.91	10.11	TOTALS.
56									1		1							2
53					1					1	1			1			1	5
50						1		2				1		1				5
47						1	1	4	3	3	2		1	1				16
44						1	1	2	2	2		3		2				13
41					1	2	4	3	2			1	2	1				16
38							5	5	1	2	1	3		1	1			19
35				1		2	2	1	3		1			1				11
32					1	2	4	5	4	3	1							20
29					3	3	2	4	1	1	1							15
26		1	2	1	6	3	2	3	1	1	1			1				22
23				2		1	2	2	2					1				10
20				2	1													3
17	1	1	1	1				1	1									6
14								1										1
11				1														1
TOTALS.	1	2	3	8	13	16	23	33	21	13	9	8	3	10	1	0	1	

$r = .461 \pm .040$

TABLE XX.— CORRELATION OF VIGOR AND STEM-LENGTH.

Long-low group, 1918–19.

VIGOR. CLASS AVE.	STEM-LENGTH. 6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	TOTALS.
100									1	1	2	4	3	5	3	1	20
95										3	1	3	4	4	3	2	20
90							1	2	4	7	7	3	4	1	3	1	33
85				1			3	4	6	7	9	3	2		1		36
80					1	2		2	5	1	4	1	2	1			19
75				1		1	1	3	1	2	2	1		1			13
70					1	1		2			1		1				6
65				1		1		2		1	1						6
60	1			1					2	2							6
55		1			1												2
50							1	1									2
45					2			1									3
40		1		1			1										3
35		1															1
30						1											1
TOTALS.	1	3	0	5	5	6	7	17	19	24	27	15	16	12	10	4	

$r = .655 \pm .029$

Table XXI.— Correlation of Vigor and Yield.

Long-low group, 1918–19.

Class Ave. (Vigor.)	Yield. 11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	Totals
100								1		2	1	1	5	3	4	1	1	1	20
95						1	1		2	1	2	3	5		4	1			20
90					2	1	2	4	4	6	4	4	5					1	33
85				2	2	3	4	9	7	2	3	1	2	1					36
80				2	2	2	2	3	1	3	3	1							19
75			1	2	2	2	3		3										13
70						3		1		1	1								6
65				1	2		1	1		1									6
60		1	2	1	1			1											6
55		1	1																2
50			2																2
45		1		1	1														3
40		2		1															3
35	1																		1
30		1																	1
Totals.	1	6	6	10	12	12	13	20	17	16	14	10	17	4	8	2	1	2	

$r = .733 \pm .023$

TABLE XXII.— CORRELATION OF YIELD AND STEM-LENGTH.

Long-low group, 1918–19.

YIELD. CLASS AVE.	STEM-LENGTH. 6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	TOTALS.
62												1			1		2
59											1						1
56											1	1					2
53										3			2	2	1		8
50											1	1	1			1	4
47								1	2	1	2	3	2	3	2	1	17
44								1	1	2			4	2			10
41						1	1		3	4	2	1			1	1	14
38					1	1		2	2	1	3	2	2	1	1		16
35				1			2	2	4	4	1		1		2		17
32					1				2	1	9	2	3		1	1	20
29							1	5	1		2	1		2	1		13
26						1		3		2	3	1	1	1			12
23					1	2	1		1	4	2	1					12
20				3			1	2	2	1		1					10
17	1				1		1	1		1				1			6
14		2		1	1	1			1								6
11		1															1
TOTALS.	1	3	0	5	5	6	7	17	19	24	27	15	16	12	10	4	

$r = .515 \pm .037$

TABLE XXIII — CORRELATION OF VIGOR AND STEM-LENGTH.

Short-high group, 1918–19

Class Ave.	6.31	6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	9.91	Totals.
	Stem-length.																			
100											2	1	2	3	2		2	1	1	14
95											3	2	7	3	3	2				20
90						1	1	1	5	3	7	4	4	3	2					31
85							3	9	3	9	6	6	2			1				39
80				1		4	4	7	5		2	2								25
75						3	2	5	1	1										12
70	1				1		4	3	1				1							11
65				2			3		1											6
60				1		1	2		1											5
55				1		2		1												4
50					2	1														3
45							1													1
40				1																1
Vigor.																				
Totals.	1	0	0	6	3	12	20	26	17	13	20	15	16	9	7	3	2	1	1	

$r = .660 \pm .028$

TABLE XXIV.— CORRELATION OF VIGOR AND YIELD.

Short-high group, 1918–19.

VIGOR. CLASS AVE.	YIELD. 14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	TOTALS.
100											1	2	2	3	2		1	1		2	14
95										2	3	1	6	4		2	1		1		20
90						1	1	2	4	5	7	4		5	1	1					31
85				2	1	2	2	9	2	8	2	3	3	1	3	1					39
80				1	2	1	4	4	4	2	2	1	3	1							25
75				1	1	1			4		3			1	1						12
70	1	1		1	3	1		1		3											11
65				1		2			2			1									6
60				1		1	1		1	1											5
55			2		1		1														4
50				1	1	1															3
45								1													1
40		1																			1
TOTALS.	1	2	2	8	9	10	9	17	17	21	18	12	14	15	7	4	2	1	1	2	

$r = .642 \pm .029$

TABLE XXV.— CORRELATION OF YIELD AND STEM-LENGTH.

Short-high group, 1918–19

YIELD. CLASS AVE.	STEM-LENGTH. 6.31	6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	9.71	9.91	TOTALS.
71															1			1		2
68												1								1
65											1									1
62											1						1			2
59											1	2				1				4
56								1		1	1	2		2						7
53						1		1		2	3	1	3	2	2					15
50						1	1		2	2			2	2	1	1	1		1	14
47							1	3			2	1	2	1	2					12
44						1	1	2	3	2	3	1	5							18
41							4	5	1	1	2	3	3	1	1					21
38				2		2	2	4	4		3									17
35						1	4	2	3	3	2	1		1						17
32							1	3	2	1		2								9
29				2		2	3	1		1	1									10
26					1	2	1	3	1							1				9
23					2	1	1	1	1			1	1							8
20				1		1														2
17				1			1													2
14	1																			1
TOTALS.	1	0	0	6	3	12	20	26	17	13	20	15	16	9	7	3	2	1	1	

$r = .536 \pm .036$

TABLE XXVI.— CORRELATION OF VIGOR AND STEM-LENGTH.

Short-low group, 1918–19.

STEM-LENGTH.

CLASS AVE.	6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	TOTALS.
100									1	1	1		2	3	1	2	11
95							1	3	1	1	5	5	1	4	3		24
90							1	2	4	3	7	4	4	3			28
85				1	1	6	3	4	8	3	3	2	1	1			33
80				2	4	5	5	6	7	5	3	1					38
75		1	1	1	4	3	2	3	6	2		1					24
70			1		2			1	3	1	1	1					10
65			1		1		2						1				5
60				1	2	1	1							1			6
55	1	1	1		2		1										6
50					1	1											2
45											1						1
40		1			1												2
35																	0
30																	0
25			1														1
TOTALS.	1	3	5	5	18	16	16	19	30	16	21	14	9	12	4	2	

VIGOR.

$r = .480 \pm .036$

TABLE XXVII.— CORRELATION OF VIGOR AND YIELD.

Short-low group, 1918–19.

VIGOR. CLASS AVE.	YIELD. 8	11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	65	TOTALS.
100											1	1	1	1		3	1	2		1	11
95						1	1	1	1	7	3	2	3	1	1	2		1			24
90						3			2	5	2	5	4	2	1	1	2		1		28
85				1		3	4	1	3	7	8	1	2		2		1				33
80					4	1	3	5	4	3	7	6	1	2	1	1.					38
75					1	3	2	3	4	5	3	1	1		1						24
70					1	3	1	2	3												10
65				1	1		2		1												5
60				2	1	2			1												6
55	1		1		2	1	1														6
50					1	1															2
45		1																			1
40				1		1															2
35																					0
30																					0
25				1																	1
TOTALS.	1	1	1	6	11	19	14	12	19	27	24	16	12	6	6	7	4	3	1	1	

$r = .592 \pm .031$

TABLE XXVIII.— CORRELATION OF YIELD AND STEM-LENGTH.

Short-low group, 1918–19.

YIELD. CLASS AVE.	STEM-LENGTH. 6.51	6.71	6.91	7.11	7.31	7.51	7.71	7.91	8.11	8.31	8.51	8.71	8.91	9.11	9.31	9.51	TOTALS.
65										1							1
62														1			1
59									1		2						3
56								1		1		1		1			4
53								1			1	1	1	2	1		7
50		1			1		1		2	1							6
47								1	1	1			1	1	1		6
44					1		1	1	3	1	1	2		1		1	12
41					1		2	2	2	4	2	1	1			1	16
38				1	1	4	3	1	4	3	3	3	1				24
35				1	1	2	3	4	4		4	1	3	3	1		27
32			1		3	1	2	3	3		3	1	1		1		19
29					1	2		2	4	2				1			12
26					3	3	2		1	1	1	1	1	1			14
23			1	2	2	1	1	3	2	1	3	2		1			19
20	1		1	1	1	3	1		2			1					11
17		1	2		2				1								6
14					1												1
11											1						1
8		1															1
TOTALS.	1	3	5	5	18	16	16	19	30	16	21	14	9	12	4	2	

$r = .377 \pm .041$